# ENVIRONMENTS AND HEALTH: ASSESSING INFLUENCES OF THE BUILT AND NATURAL ENVIRONMENT ON MENTAL AND PHYSICAL HEALTH

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# ENVIRONMENTS AND HEALTH: ASSESSING INFLUENCES OF THE BUILT AND NATURAL ENVIRONMENT ON MENTAL AND PHYSICAL HEALTH

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The present dissertation focused on influences of the built and natural environment on mental and physical health. Three studies examined environmental attributes associated with mental and physical health within children's most proximate settings: homes, neighborhoods, and schools:

Chapter 2: Research about how residential design attributes may moderate effects of crowding on children's psychological health is sparse. This two-part, cross-sectional study first examined the relation between residential interior density and self-reported crowding among children. Second, analysis investigated the potential role of residential design attributes - floor plan arrangement, child's bedroom ceiling height, volume, and window area - to buffer adverse effects of crowding on children's psychological health and physiological stress. Results suggested that bedroom ceiling height may moderate negative effects of home and bedroom crowding on children's psychological health and physiological stress.

Chapter 3: The amount of nature needed for humans to achieve the well-documented benefits of nature exposure is unknown, partially because no common nature measure exists. This study developed and tested a nature estimation method, using freely available Google Earth satellite images, to address estimation limitations of 2006 National Land Cover Database and automated Geographic Information Systems procedures. Amounts of nature (vegetation, trees, water) surrounding a sample of New York residences were estimated and compared using both methods. The Google Earth method better estimated nearby nature in dense, highly developed urban areas, while either estimation method was appropriate for less densely populated areas.

Chapter 4: Based on environmental psychology and behavioral economics strategies associated with healthy eating, the Cafeteria Assessment for Elementary Schools (CAFES) offers an objective, reliable, and valid instrument that quantifies physical cafeteria attributes linked to selection and consumption of fruits and vegetables (FV) at the scale of room, table, plate, and food.  Observations, interviews, and FV serving and consumption data obtained from lunch tray photography were used to develop and validate CAFES.  Total CAFES and four scale scores were associated with FV consumption outcomes.  Researchers and practitioners can use CAFES to identify critical areas for intervention; suggest low- and no-cost intervention strategies; and contribute to design guidelines aimed at promoting healthy eating among elementary school students.

## BIOGRAPHICAL SKETCH

Kim Rollings was born in Chicago Heights, Illinois. She lived in Matteson, Illinois with her parents and younger brother until attending college at the University of Notre Dame in South Bend, Indiana. When Kim was not in architecture studio or volunteering with service projects, she actively participated in campus music programs and served as a drum major for the University of Notre Dame Marching Band. She also enjoyed the required year abroad to study architecture in Rome, Italy before graduating with a Bachelor of Architecture degree in 2003. Kim and her husband met as Notre Dame Band flute and piccolo players, and later returned to Notre Dame to marry in June, 2008.

Before beginning graduate school at Cornell, Kim was employed as an architect for primarily residential architecture firms. She also completed research methods and architecture and human behavior courses at Columbia University and the University of Wisconsin-Milwaukee. After working as a project architect in New York City, Kim joined Cornell's graduate program in Design and Environmental Analysis full-time to explore interests in architecture and health. Upon completing her Master's degree, she remained at Cornell to pursue a doctoral degree in the newly established Human Behavior and Design Ph. D. program. Kim will join the faculty of an architecture department where she will continue her research and teach environment-behavior, health, and sustainability research courses and design studios.

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CHAPTER 1

# INTRODUCTION

*"Our bodies, our health, and our buildings are forever connected. The links between architecture and well-being are richer than merely affording safety from injury; buildings can be, should be, agents of health – physical, mental and social health. Good buildings and urban plans do precisely that." -Richard J. Jackson (Rainwater, Brown, & Haber, 2012; p. 2)*

Despite the successes of modern public health, many challenges still remain. The World Health Organization broadly defines health to include overall physical, mental, and social well-being beyond the absence of disease, injury, or pain (World Health Organization, 2011). Health applies not only to individual people, but is also discussed in terms of healthy buildings, communities, cities, and environments. Determinants of health and health behaviors include cultural, political, economic, environmental, and biological factors. Influences of the physical environment, especially, on health have received increased attention in recent decades. The present doctoral dissertation focused on influences of the built and natural environment on mental and physical health. Each of three studies examined environmental influences within one of children's three most proximate settings: home, neighborhood, and school.

## *The Physical Environment*

Work examining links between the physical environment and health has primarily focused on neighborhood and urban scale design factors (e.g., land use, land cover, safety, transportation, resource access, walkability, air and water quality, sanitation, etc.). Until recently, most work at the building scale has concentrated on the relation between physical health and chemical toxicants (e.g., indoor air quality, radon, lead poisoning, sick building syndrome etc.). The dimensionality of building-scale environmental influences on health, however, extends beyond materials and building systems. Social and physical factors within buildings, where people spend as much as 90% of their lives (Evans & McCoy, 1998), interact with each other and larger scale factors to affect individual and collective health.

Three public health challenges linked to the physical environment - poor quality and crowded housing, a lack of access to nature especially in urban areas, and childhood obesity – are each individually addressed in three chapters of this dissertation. First, the prevalence of crowded housing conditions in the U.S. is increasing (Mackun, Wilson, Fischetti, & Goworowska, 2011). Baby boomers (Engelhardt & Greenhalgh-Stanley, 2008; Orsini, 2007) as well as unemployed adult children (Taylor, Passel, Fry, Morin, & Wang, 2010) seeking smaller, affordable housing move in with relatives to reduce expenses. Yet, despite increases in high density living, the U.S. housing market is simultaneously experiencing an emerging downsizing trend. The ongoing energy crisis, in addition to the economic downturn, is further inspiring smaller, adaptable, more affordable housing options (Cusato, Ruiz, & LaLiberté, 2010; Hood & Sakal, 2008).

Second, maintaining access to natural areas as the population increases, especially in densely developed urban locations where most of the growing population will reside, will become even more difficult. This population increase is problematic considering empirical evidence indicating exposure to nature benefits human physical and mental health, cognitive functioning, and well-being (Frumkin, 2001; Wells & Donofrio, 2011; Wells & Rollings, 2012).

Third, in addition to crowded housing and a lack of nature exposure, overweight, obesity, and related chronic diseases have reached epidemic levels. Adult obesity rates have doubled and childhood rates have tripled in only 30 years (Flegal, Carroll, Ogden, & Curtin, 2010). The obesity crisis is particularly concerning because of the associated negative physical, social, and mental health consequences (Must et al., 1999), as well as healthcare costs (Cawley, 2010). Annual direct and indirect costs of treating obesity-related illnesses and conditions are expected to exceed an estimated 112 billion dollars (Centers for Disease Control and Prevention, 2010). Addressing these and other public health-related challenges requires an understanding of the complex, multilevel factors within our surrounding environments that affect both mental and physical health.

***Social-ecological models***

Social-ecological models provide frameworks for conceptualizing the complex, multilevel factors, including the physical environment, that affect health. Interdisciplinary in nature, social-ecological frameworks align with current approaches utilized in the field of public health and related disciplines (Institute of Medicine, 2001; National Academies Press, 2005; U.S. Department of Health and Human Services, 2000). Focus has shifted from an individually-centered, educational intervention approach toward an emphasis on larger-scale environmental and policy factors, cross-scale interactions, and how multilevel interactive factors relate to health and health promotion (Sallis, Bauman, & Pratt, 1998; Stokols, 1992). At each level of analysis, social-ecological frameworks identify environmental attributes and behavioral patterns relevant to health outcomes of interest. Frameworks also highlight specific opportunities or leverage points for health promotion (Stokols, 1992). By recognizing influences of and interactions between individual, familial, environmental, societal, and policy-related factors at various scales, the ecological perspective suits the challenging, multiscalar, and interdisciplinary issues surrounding health.

*Bronfenbrenner's ecological model of human development* (Figure 1.1) provides a useful foundational framework for examining links between the physical environment and health. The model identifies four scales of our surrounding environment, or "context," that assist in conceptualizing environmental influences and interactions between factors at various scales: *microsystem, mesosystem, exosystem*, and *macrosystem* (Bronfenbrenner, 1979, 1994). A *microsystem* is a pattern of relationships and interactions between individuals and their immediate surroundings, such as families at home (Bronfenbrenner, 1979, 1994). These interactions, known as proximal processes, are defined as regularly reoccurring interactions between an individual, genetics, and other physical, social, and symbolic environmental features necessary for human development (Bronfenbrenner, 1994). *Mesosystems* are relations between two or more microsystems (e.g., home and school), each containing the individual. *Exosystems* are comprised of interactions between two or more settings, where at least one setting does not include the individual but indirectly influences proximal processes within other immediate settings (e.g., for a child, his/her home and a parent's place of work). *Macrosystems* are broad societal patterns of micro-, meso-, and exosystems (e.g., economy, government, and cultural values) that refer especially to a culture or subculture's typical beliefs, knowledge, resources, customs, and life-styles (Bronfenbrenner, 1994). Additionally, the *chronosystem* further acknowledges changes or consistency in both individuals and environments over time (Bronfenbrenner, 1994).

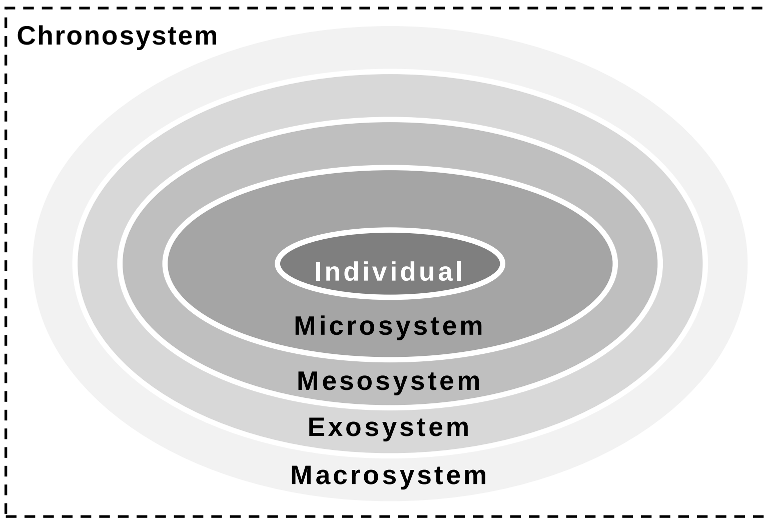


***Figure 1.1.*** *Bronfenbrenner's ecological model of human development*

Social-ecological models of health and health behaviors are based on four assumptions concerning human health and the development of effective prevention and intervention strategies. First, the relationship between health and the environment is multilevel. Second, interactions between influential factors occur across levels to affect health and health behaviors. Third, examinations of health-promotive settings should address the complex, multidimensional nature of environments (Sallis, Owen, & Fisher, 2008). Environmental qualities can be physical or social; objective (actual) or subjective (perceived); multiscalar (proximal vs. distal; Stokols, 1992); and described individually (e.g., group size, lighting, and layout) or by relationships among a group of elements, such as those described by the concept of behavior settings (Stokols, 1987)[1]. Fourth, health and health behaviors are influenced by physical, social, and individual factors (e.g., biology, genetics, health behaviors; Sallis et al., 2008; Stokols, 1992). Health behaviors are believed to improve when attributes of both the physical and social environment support and motivate healthful choices. Simply providing a health-promotive environment (e.g., access to healthy food, physical activity opportunities, and transportation) is not enough; social supports (e.g., policies and incentives) are needed to encourage people to take advantage of those resources (Sallis et al., 2008).

### ***Affordances***

Attributes within the environment that promote or hinder behaviors, including those related to health, are also known as affordances. An affordance, according to environmental psychology, describes a group of elements within an environment that present the opportunity for or allow a particular behavior to occur (Gibson, 1977). Affordances within the environment influence health by serving as either supports that facilitate or barriers that hinder healthy behaviors. Environmental supports within school cafeterias, for example, can facilitate or encourage students to select healthy meal options. Barriers, on the other hand, such as increased availability and variety of unhealthy options in school cafeterias, hinder the selection of healthy options. Individuals' perceptions of affordances, however, influence whether a particular behavior will occur (Alfonzo, 2005). Because people's perceptions of affordances differ, even within the same setting, perceptions can act as a mediator of the relation between environment and health. By considering people's perceptions and motivations, environmental interventions aimed to improve health must increase supports of and decrease barriers to health and health behaviors.

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[1] Behavior settings are the locations and situations where common behavior patterns occur (Barker, 1968). Critical social and physical environmental features are linked to these behavior patterns, such as a table and chairs within a dining area where eating occurs.

### ***Dissertation overview***

The following collection of three dissertation studies falls under the broad umbrella of "environments and health." Each study focuses on physical environment attributes within one of three settings - homes, neighborhoods, and schools - that interact with factors at other scales of Bronfenbrenner's model to affect mental and physical health. First, *Potential design moderators of the residential crowding – psychological health and crowding – physiological stress relations among children* (Chapter 2), a cross-sectional study, examined correlations between residential interior density and children's self-reported home and bedroom crowding. Additional analyses investigated the potential role of residential floor plan arrangement (measured by space syntax concepts of depth and permeability), child's bedroom ceiling height, volume, and window area to buffer adverse effects of home and bedroom crowding on psychological health and physiological stress. The second study, *Objectively quantifying nearby nature: Land cover data and automated GIS procedures vs. manually-rated satellite images* (Chapter 3), developed and tested a method for measuring nearby nature that addressed limitations of using land cover data to estimate nearby nature in urban areas. The study contributed to the development of a common nature metric needed to facilitate cross-study comparisons and identify "doses" of nature exposure associated with mental and physical health benefits.

With data from 50 low-income elementary schools and 2,000 National School Lunch Program participants in four states, the third study, *Cafeteria assessment for elementary schools (CAFES): Instrument development* (Chapter 4), developed a tool to quantify physical cafeteria attributes that encourage and hinder healthy eating during school meals. By identifying physical attributes associated with elementary students' healthy eating at four environmental scales (room, table, plate, and food), CAFES can be used to identify critical areas for intervention; suggest low- and no-cost intervention strategies; and contribute to cafeteria design guidelines aimed at promoting and increasing fruit and vegetable consumption among elementary schools students.

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CHAPTER 2

# POTENTIAL DESIGN MODERATORS OF THE RESIDENTIAL CROWDING – PSYCHOLOGICAL HEALTH AND CROWDING - PHYSIOLOGICAL STRESS RELATIONS AMONG CHILDREN


## ABSTRACT

Chronic residential crowding can adversely affect psychological health, yet research on how residential design attributes may moderate negative effects of high interior density (people per room) living conditions is sparse. This two-part, cross-sectional study first examined correlations between residential interior density and children's self-reported bedroom and home crowding. Second, analysis investigated the potential role of residential floor plan arrangement (measured by space syntax concepts of depth and permeability), child's bedroom ceiling height, volume, and window area to buffer adverse effects of crowding on psychological health and physiological stress. Measures of psychological health included reports from the child's mother; learned helplessness; and child-reported psychological distress and perceptions of psychological well-being. Physiological stress indices included resting systolic and diastolic blood pressure; overnight urinary neuroendocrine measures of cortisol, epinephrine, and norepinephrine; and allostatic load. Interior density significantly predicted home and bedroom crowding when controlling for income-to-needs and gender, but interior density and crowding were only modestly correlated. Regression results, controlling for income-to-needs, suggested that children's bedroom ceiling height buffered the negative effects of home crowding on blood pressure, epinephrine, norepinephrine, and allostatic load, and the negative effects of room crowding on learned helplessness and psychological health, especially among participants who reported higher crowding. Although the study was one of few to examine the understudied potential of design attributes to buffer adverse effects of crowding on children, additional research is needed to determine whether design attributes can moderate the crowding-psychological health and crowding-physiological distress relations among children.

## INTRODUCTION

Research has demonstrated that chronic residential crowding can negatively affect psychological health and physiological stress (*see reviews*: Evans, 2003a; Evans, 2006; Leventhal & Newman, 2010). Young children, especially those not in day care, spend more time at home than in any other environment (Hofferth & Sandberg, 2004), yet few studies have examined how design attributes within a home might buffer the negative effects of residential crowding on children in high interior density living conditions (Evans, Lepore, & Schroeder, 1996; Schiffenbauer, Brown, Perry, Shulack, & Zanzola, 1977). This cross-sectional study examined associations between interior density and children's reported crowding, as well as whether residential design elements such as window area, ceiling height, volume, and floor plan arrangement moderated the effects of crowding on children's psychological health and physiological stress.

### *Interior density and crowding defined*

Density has been defined in a number of ways. In the planning field, the term "density" refers to neighborhoods and cities (i.e., number of people per acre), while "crowding" refers to the density of interior spaces (Forsyth, Oakes, Schmitz, & Hearst, 2007). In this paper, *interior density* refers to the number of persons per room. *Crowding*, according to environmental psychologists and in this paper, is defined as an individual psychological response to high interior density based on perceptions of spatial restriction due to too little space or too many people present in a space (Aiello, Epstein, & Karlin, 1974; Evans, Saegert, & Harris, 2001; Stokols, 1972; Sundstrom, 1975). The number of residents per room, rather than square footage per person or areal measures of density (e.g., people per acre), is significantly correlated with indicators of psychological health and often used to quantify crowding (Baum & Paulus, 1987). High interior density living conditions are aversive if they induce the psychological state of crowding (Stokols, 1972) via one of several mechanisms, including: an induced feeling of loss of control, especially over desired social interaction (Altman, 1975); a state of over-arousal or over-stimulation (Evans, 1979); social hassles interfering with attainment of a valued goal or daily activities (Lepore, Evans, & Palsane, 1991; Olson, 1975; Schiffenbauer, 1975; Schiffenbauer et al., 1977); or interference with socially supportive relationships among home residents leading to social withdrawal (Baum, Gatchel, Aiello, & Thompson, 1981; Baum & Valins, 1979; Evans & Lepore, 1993; Evans, Palsane, Lepore, & Martin, 1989; Evans, Rhee, Forbes, Allen, & Lepore, 2000; Lepore et al., 1991; Lepore, Merritt, Kawasaki, & Mancuso, 1990; Stokols, 1976; Wells, 2005). The following sections discuss (1) the potentially adverse effects of crowding on children's psychological health and physiological stress and (2) previous research that suggests floor plan arrangement (measured by space syntax concepts of depth and permeability), ceiling height, and window area may moderate the crowding-psychological health and physiological stress relations.

***Adverse effects of crowding***

Many cross-sectional studies (Baum et al., 1981; Baum & Valins, 1979; Evans, 2003a; Evans & Lepore, 1993; Evans et al., 1996; Evans et al., 1989; Evans et al., 2000; Evans et al., 2001; Lepore et al., 1991) and two prospective, longitudinal studies (Lepore et al., 1991; Wells & Harris, 2007) have found adverse effects of chronic residential crowding on adults' psychological health. Although a substantial portion of the residential crowding literature focuses on adults, several studies (*see reviews*: Evans, 2006; Leventhal & Newman, 2010) have examined adverse effects of crowding on children's outcomes including behavior, academic performance, cognitive processes, child development, and the focus of the current study: psychological health. Earlier work on crowding and children controlled for socioeconomic status (SES), but did not use a standardized instrument to assess children's psychological health. Despite this limitation, results indicated that children from higher interior density homes had more *behavioral problems* in the classroom (Saegert, 1982). Greater *conflict* also occurred among parents and children in more crowded homes (Booth & Edwards, 1976; Evans, Lepore, Sejwal, & Palsane, 1998; Saegert, 1982). Crowding can also affect children's psychological health and development indirectly via effects of crowding on parents' behaviors. Parents in higher interior density homes tend to be more *critical* and *less responsive* to their young children (Bradley & Caldwell, 1984; Evans, Maxwell, & Hart, 1999; Wachs, 1989).

One study that did use a standardized index of psychological health (Rutter, Tizard, & Whitmore, 1970) found significant associations between interior density and *psychological health* among both rural and urban children (third through fifth graders) living in poverty (Evans et al., 2001). Poor housing quality, including crowded conditions, is a major source of stress and worry especially for low-income families (Evans, 2004; Evans, Lercher, & Kofler, 2002). Children exposed to chronic crowding, compared to children not exposed to chronic crowding and noise, are less likely to persist on challenging tasks, also known as *learned helplessness* (Evans et al., 1998; Evans et al., 2002; Evans et al., 2001; Rodin, 1976).[2] Evans, Lercher, and Kofler (2002) further examined the effects of crowding on self-reports of rural and small town children's psychological health, in addition to children's behavioral conduct reported by teachers. Participants resided in single family detached homes, row houses, and multiple family dwellings. Results confirmed that more adverse effects of crowding were experienced by children living in higher interior density, multi-family dwellings.

The relation between crowding and associated negative outcomes, however, varies by gender. In the Evans and colleagues (2001) study, child participants from higher interior density, multiple family dwellings were less likely to persist on problem-solving tasks, but rural boys were more vulnerable to the adverse psychological outcomes of high interior density living conditions than girls. Another study found that the association between crowding and learned helplessness was significant only for 10- to 12-year-old girls, and between crowding and blood pressure for 10- to 12-year old boys (Evans et al., 1998).

[2] The decrease in task persistence is likely due to a lack of control over social interactions in high density living conditions that influences self-efficacy and helplessness (Evans et al., 2001; Rodin, 1976).

Only a few studies have explored the effects of crowding on children's *physiological stress* (*see review*: Evans, 2006). A laboratory study found that boys, but not girls, in crowded conditions had higher skin conductance levels; levels were even more elevated with longer exposure (Aiello, Nicosia, & Thompson, 1979). Another study found that 8- to 10-year-old boys and girls from higher interior density apartments, especially with greater family turmoil, had elevated overnight epinephrine and norepinephrine levels (Evans & Saegert, 2000). In another study of 10- to 12-year olds, gender moderated the interior density-blood pressure relation such that increases in crowding were significantly associated with increases in blood pressure among boys when controlling for household income (Evans et al., 1998).

Several studies within publications about children and crowding examined gender as a moderator, controlled for socioeconomic status, and utilized standardized instruments to assess children's psychological health; not all studies, however, included a wide range of residential interior densities (Evans, 2003a), or examined potential moderators that might buffer the adverse effects of crowding on children. Some evidence suggests that, conceivably, physical design elements within a residence may moderate negative effects of crowding on children.

***Crowding and residential design elements: potential moderators***

Schiffenbauer and colleagues concluded that "significant variation in crowdedness ratings with no variation in physical (interior) density indicated that (interior) density is neither a necessary nor sufficient condition for crowding to occur" (1977, p. 13). Schiffenbauer's team (1977) studied dormitory rooms of equal size and interior density (equal number of people per room), but perceptions of crowding differed based on usable space, greater vistas afforded by higher floor level, and amount of natural light. Reduced usable space increased perceptions of crowding possibly because it elicited a lack of control over room layouts that may have afforded additional privacy. Window views from higher floor levels and more natural light, conversely, reduced perceptions of crowding. Although this study suggested that residential design attributes may moderate the interior density-crowding relation, results were based on self reports from all female college students and did not consider alternative explanations for differences in crowding perceptions. These findings were replicated and expanded upon by Kaya and Erkip (2001), who found that both male and female dormitory residents perceived rooms of equal size and interior density on higher floor levels as less crowded than those on lower floor levels. Conclusions were still based entirely on self-reports and failed to consider alternative explanations, such as differences in noise between lower and upper floors. In addition to physical size, usable space, floor level, and natural light, additional research offers evidence that design elements such as residential floor plan arrangement, window area, and ceiling height could buffer the adverse effects of crowding on children.

*Floor plan arrangement and space syntax*. High interior density residential floor plans can be architecturally arranged in several ways (Mitchell, 1971). The need for privacy and to control desired levels of social interaction (Aiello et al., 1974; Altman, 1975; Evans et al., 1996; Sundstrom, 1975) suggests that, given the same square footage, perceptions of high interior density living conditions may vary based on floor plan arrangement. Increased depth could afford desired levels of privacy and social interaction, reducing *social withdrawal* (Evans et al., 2000; Lepore et al., 1990; Wells & Harris, 2007). Several studies have linked floor plan arrangement to reduced perceptions of crowding among college students. A dormitory containing long corridors that was converted into suite arrangements resulted in (self-reported) reduced negative outcomes of crowding, more social engagement, and less social withdrawal (Baum & Davis, 1980). Other studies found that prison inmates experienced lower levels of reported crowding and associated negative physiological effects in a cubicle rather than a more open floor plan arrangement, both with a similar amount of square footage, because of the afforded privacy (Cox, Paulus, McCain, & Karlovac, 1982; Schaeffer, Baum, Paulus, & Gaes, 1988). One of these studies included objective physiological measures of stress hormones in addition to self-reported measures (Schaeffer et al., 1988). The variations in floor plan arrangements within each of these studies can be measured by space syntax concepts of *depth* and *permeability*.

Part of the theory of *space syntax*, developed by Hillier and Hanson (1984), describes how attributes of residential floor plan layouts, such as depth and permeability, can influence social interaction. *Depth* is defined as the number of spaces or thresholds that must be traversed before reaching a specific destination within a floor plan. While depth is a measure that describes floor plan layout, *permeability* relates more to connectivity and openness. Permeability, a concept often used to describe urban forms, also describes how floor plan layouts affect movement throughout a home (Hillier & Hanson, 1984). Permeability captures the accessibility of spaces and floor plan configurations, or how public and private they are, and can be quantified by the space syntax concepts of relative asymmetry (RA) and real relative asymmetry (RRA; Hanson, 2003). RA is a function of the plan's mean depth and number of rooms, and RRA is a function of RA and depth of interconnected spaces. Low values indicate highly public, integrated, and accessible spaces and plan configurations while high values indicate more private spaces and plan configurations. Permeability also affords or inhibits control of stimulation and social interaction that can affect perceptions of crowding (Hillier & Hanson, 1984). An example floor plan and associated depth diagram are presented in Figure 2.1.

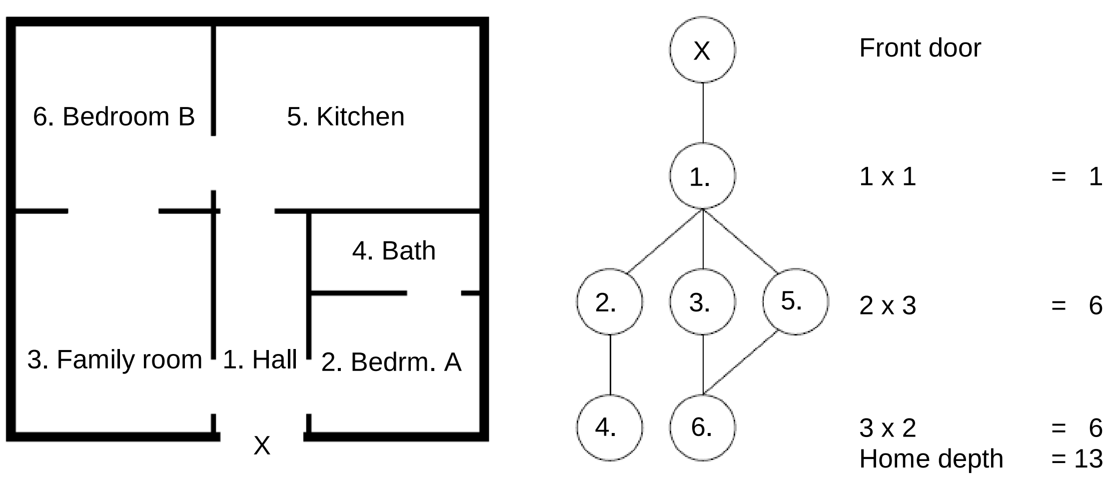


***Figure 2.1.*** *Example floor plan and home depth diagrams*

In a promising study on residential environments concerning floor plan arrangement and children's crowding, space syntax theory's concept of architectural depth was explored as a moderator of the crowding-psychological distress relation in college students (Evans et al., 1996). The study found that greater architectural depth moderated the interior density-psychological distress relation through added opportunities to regulate social interaction and reduced social withdrawal (mediated moderator); therefore, negative effects of crowding on psychological distress were reduced. This supported findings that children living in crowded homes who can retreat to a space of their own suffer fewer negative effects of crowding (Wachs & Gruen, 1982).

*Child's bedroom ceiling height and window area*. Although space syntax provides useful methods to quantify differences in two-dimensional floor plan arrangements, the theory does not capture three-dimensional design elements, such as *ceiling height* or *window area* that potentially affect perceptions of room size, moderate the interior density-crowding relation, or buffer negative effects of crowding.

*Ceiling height*. People perceive rooms with lower ceilings as smaller, offering less physical space, and therefore require more personal space; however, a room of the same size with a higher ceiling is perceived as larger and offering more personal space, so people require less personal space and are willing to tolerate more social interaction (Savinar, 1975).

*Windows.* Evidence from a few studies has suggested that natural light and views provided by windows, affected by window size, can influence perceptions of room size and crowding (Butler & Steuerwald, 1991; Ne'eman & Hopkinson, 1970; Schiffenbauer et al., 1977). Any window view is preferred over no view (Collins, 1975), and expanded window views afforded by higher floor level were found to reduce perceptions of crowding (Schiffenbauer et al., 1977). College students perceived dormitory rooms that received more natural light as less crowded than darker rooms (Baum & Davis, 1976; Schiffenbauer et al., 1977). Dormitory studies, however, did not account for window size. Additional previous studies have also examined the effect of room size, natural light, and window view on window size preferences. In smaller rooms, a larger window in proportion to the wall was preferred (Butler & Steuerwald, 1991). The scant number of windows studies, however, suffered from several limitations. Participants of varying sociodemographic factors were not included. Studies that examined window size preference were conducted in controlled laboratory settings using constructed models, limiting external validity.

### *Current study*

Few studies have examined the relation between interior density and crowding among children. Furthermore, research about how residential design attributes buffer adverse effects of crowding, especially among children, is sparse. Conceivably, design attributes such as floor plan arrangement, ceiling height, and window area that may affect social interaction within a home, as well as perceptions of space and high interior density living conditions, could moderate crowding-psychological health and crowding-physiological stress relations among children. The present study first examined associations between residential interior density and children's crowding, then explored the understudied potential of design elements – floor plan arrangement, ceiling height, volume, and window area – to moderate children's crowding-psychological heath and physiological stress relations.

### *Research aims*

*Aim 1: Determine whether interior density was a "sufficient" indicator of children's reported home and bedroom crowding in this sample.* Although interior density is often used as a proxy for crowding (Baum & Paulus, 1987; Evans et al., 2001), Schiffenbauer and colleagues' conclusion that "(interior) density is neither a necessary nor sufficient condition for crowding to occur" (1977, p.13) was examined. Initial analyses explored the hypothesis that higher interior densities are strongly correlated with and predict children's self-reports of both overall home and bedroom crowding (Figure 2.2).

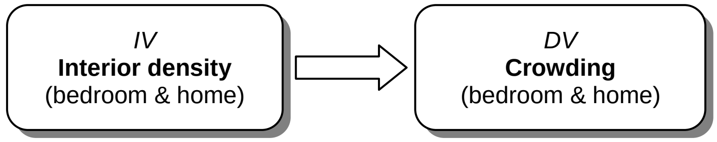


***Figure 2.2.*** *Interior density-crowding relation*

<u>*Aim 2*</u>: *Determine whether the residential crowding- psychological health and crowding–physiological stress relations among children were moderated by the target child's bedroom (TCB) window area, ceiling height (lowest point), volume, depth, home depth, or home permeability* (Figure 2.3). The hypothesis was that greater TCB window area, ceiling height, volume, and depth would moderate negative effects of TCB crowding, and that mean home depth and permeability would buffer the negative effects of home crowding.[3]

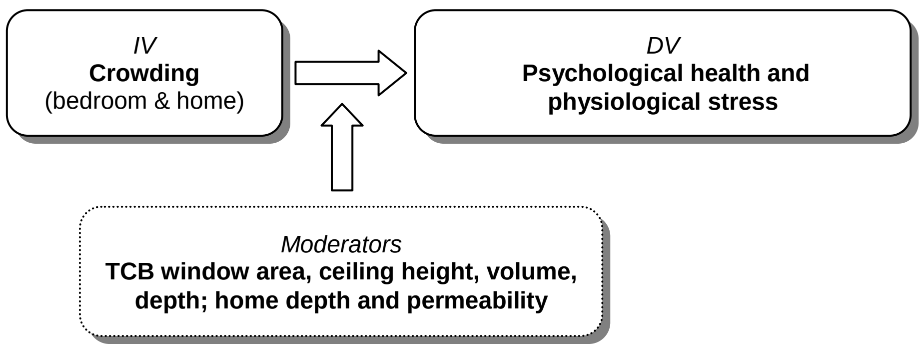


**Figure 2.3.** *Potential design attribute moderators of the crowding-psychological health and physiological stress relations*

## METHODS

### *Research design and participants*

Secondary, cross-sectional data were extracted from the first wave of a longitudinal data set collected between 1995-2006 (mean ages: wave 1=9, 1995-1999; wave 2=13, 1997-2003; wave 3=17, 2002-2006). Home interviews with 341 low and middle income children and their mothers were originally conducted during two home visits by trained research assistants following a uniform protocol. Data were gathered on housing quality, psychological health, physiological stress, and demographics of one "target child" and his or

[3] Results of main effects analysis revealed that crowding, not interior density, predicted children's psychological health and physiological stress. Therefore, crowding was used in Aim 2 analyses.

her female parent or guardian. The sample was mostly white and resided in primarily rural areas throughout upstate New York in the Finger Lakes region. Trained research assistants also sketched participants' home floor plans and recorded information about children's bedroom design for a subset of 181 children at age 9 (Wave 1). This subset of children, floor plans, bedroom design information, and outcome data was analyzed in the current study. Sociodemographic and descriptive information concerning this subset of youth and their home environments is displayed in Table 2.1.

***Table 2.1. Participant sociodemographic and descriptive statistics***

| Variable | n | Variable Levels | Total | | Mean | *SD* | Range |
|---|---|---|---|---|---|---|---|
| | | | # | % | | | |
| **Gender** | 181 | Male<br>Female | 90<br>91 | 50<br>50 | -- | -- | -- |
| **Age** (years) | 181 | -- | -- | -- | 9 | *1.25* | 6 - 12 |
| **Income-to-needs ratio**[4] | 181 | -- | -- | -- | 1.14 | *0.65* | 0.10 - 3.74 |
| **BMI**[5] | 127 | -- | -- | -- | 18.61 | *3.60* | 12.35 - 33.31 |
| **Home ownership** | 181 | Own<br>Rent | 57<br>124 | 32<br>68 | -- | -- | -- |
| **Home area** (SF) | 90 | -- | -- | -- | 1007.85 | *371.79* | 131.67 - 2366.24 |
| **No. of rooms in residence** | 181 | -- | -- | -- | 10.47 | *2.80* | 5 – 19 |
| **Home interior density** (average persons/room) | 181 | -- | -- | -- | 0.66 | *0.21* | 0.25 - 1.25 |
| **TCB density** (persons/room)* | 180 | 1<br>2<br>3<br>4<br>Missing | 105<br>64<br>8<br>3<br>1 | 58<br>35<br>4<br>2<br>1 | 1.49 | *0.66* | 1 – 4 |
| **Home crowding score** (0-18) | 180 | -- | -- | -- | 11.80 | *3.46* | 2 – 18 |
| **TCB crowding score** (0-18) | 164 | -- | -- | -- | 11.64 | *4.21* | 0 – 18 |
| **TCB window area** ($in^2$) | 88 | -- | -- | -- | 1503.09 | *823.37* | 442–5427 |
| **TCB ceiling height** (high; ft) | 132 | -- | -- | -- | 7.61 | *0.90* | 6.33 - 14.31 |
| **TCB ceiling height** (low; ft) | 132 | -- | -- | -- | 7.07 | *1.64* | 2.17 - 14.31 |
| **TCB volume** ($ft^3$) | 89 | -- | -- | -- | 868.53 | *282.78* | 440.77 - 1846.57 |
| **TCB depth** | 181 | -- | -- | -- | 27.97 | *14.39* | 7 – 79 |
| **Mean home depth** | 181 | -- | -- | -- | 2.56 | *0.51* | 1.60 - 3.85 |
| **Home permeability** | 181 | -- | -- | -- | 0.68 | *0.15* | 0.37 - 1.09 |

**TCB=target child's bedroom; TCB density was a continuous variable*

[4] Refer to the *Constructs and measures: Independent variables* section for a definition.
[5] Body mass index. See "*Constructs and measures*" section.

***Constructs and measures: Independent variables***

*Interior density* (home) was defined as the number of persons per room (excluding hallways, attics, closets, garages, etc.) recorded by trained research assistants during the home interview visit.

*Interior density* (target child's bedroom) was defined as the number of persons sharing the target child's bedroom (TCB), recorded by trained research assistants during the home interview visit.

*Home crowding* was assessed by nine items. Children were asked to indicate on a three-point scale (always, sometimes, never), answers to questions such as, "Do you wish your house was bigger," "Do you feel squished in your house," and "Do people get in your way in your house?" Items were appropriately coded and summed to yield a total house crowding score.

*Target child's bedroom (TCB) crowding* was evaluated using a modified version of the nine crowding-related items used to assess home crowding. Questions were reworded to apply to the target child's bedroom instead of the entire home. Items were appropriately coded using the same three-point scale and summed to generate the target child's bedroom crowding score.

*TCB window area* was calculated using window height and width measurements recorded by trained research assistants using a tape measure. All window areas were summed to calculate the total bedroom window area. The percentage of wall area that was windows could not be calculated because detailed wall dimensions were not recorded in the original data set. Window treatments were also not recorded.

*TCB ceiling height* was measured by trained research assistants using a tape measure. Both the highest and lowest points of children's bedrooms were noted to account for sloped ceilings. The lowest ceiling height was used in this study's analysis.

*TCB volume* ($ft^3$) was calculated using TCB length, width, and average ceiling height measurements gathered by trained research assistants using a tape measure. Although no prior work has examined the role of volume as a moderator of the crowding-psychological health relation, this variable captured both two- and three-dimensional attributes of the TCB size that could affect perceptions of high interior density conditions.

*Depth* (mean home and TCB) and *permeability* (home) were calculated as described in the introduction, based on trained research assistants' sketches of participants' home floor plans. TCB depth was calculated for the child's bedroom. Mean home depth and home permeability were calculated using the following formulas:

*Mean home depth* = Sum of all individual space depths/(K-1) where *K*=number of spaces.

*Home permeability* (real relative asymmetry or RRA) = RA/$D_K$ *where:*

RA= relative asymmetry= 2(Mean Depth - 1)/(K-2)

$D_K$ = RA for diamond shaped complexes of K cells= 2[K{log2((K+2)/3)-1}+1]/[(K-1)(K-2)]

K=number of spaces

*Gender* (control, Aim 1). The target child's gender was recorded and controlled for in Aim 1 analyses.

*Income-to-needs ratio* (control, Aims 1 & 2). The income-to-needs ratio is a measure of family income and is defined as the cash income level of the child's family divided by the official poverty line for that family size at the time of data collection. Thus, an income-to-needs ratio of one indicates at the poverty line. The target child's mother or guardian provided research assistants with family income and size.

***Constructs and measures: Dependent variables***

*Children's psychological health* was operationalized using five age-appropriate measures gathered by trained researchers during "Wave 1" of the greater longitudinal study:

1. The *Rutter children's behavior questionnaire* (Cronbach alpha = 0.83; Boyle & Jones, 1985; Rutter et al., 1970), a widely-used standardized instrument with well documented psychometric properties, measures psychological health in nonclinical samples of young children (Boyle & Jones, 1985; Evans et al., 2001; Rutter et al., 1970). The child's mother rated the 26 items on a three-point scale (0=does not apply, 1=applies somewhat; 2=certainly applies) that related to childhood symptoms of anxiety, depression (e.g., "often

worries, worried about many things"), and behavioral conduct disorders (e.g., "bullies other children"). Higher scores indicated worse behavior associated with poorer psychological health.

*2.* *Learned helplessness*, related to human motivation (Evans, 2001b), was measured using an age-appropriate behavioral index that assessed persistence (time in seconds) on a challenging task. A standard behavioral protocol (Glass & Singer, 1972) was adapted for nine-year-olds (Cohen, Evans, Stokols, & Krantz, 1986). The challenging task consisted of giving the target children a puzzle in which they had to "visit" each object (e.g., an animal) on the paper by drawing over interconnecting lines without lifting the pencil or doubling back on any line. Participants were given instructions, a practice round using an easy version of the task, and then told to work on the challenging version until solved or they felt unable to do so. Target children were then given a readily solvable version of the puzzle, but the primary index of helplessness was persistence on the first challenging puzzle. Longer length of time indicated longer persistence associated with better psychological health.

3. *Psychological distress* was measured using the standardized 25-item Demoralization Index of the Psychiatric Epidemiology Research Instrument (PERI) for nonclinical populations (Dohrenwend, Shrout, Egri, & Mendelsohn, 1980). Participants indicated on a five-point scale (never to very often) whether they experienced a specific symptom (e.g., "felt lonely") in the previous three months. Total scores were created by summing all items. Items included questions such as, "How often have you been bothered by feelings of sadness or depression," "How often have you felt confident," and "How often have you felt anxious?" Items were coded such that higher scores indicated worse distress associated with poorer psychological health.

4. *Social withdrawal* (*see reviews*: Evans 2006; *also* Evans et al., 1996) was measured by the sum of an eight-item scale. Items related to how frequently participants felt thoughts and behaviors regarding the avoidance of social interaction and required

participants to respond on a five-point scale (0=never, 4=very often). Lepore and colleagues (1990) found this measure to be reliable (Cronbach alpha=0.93). Higher social withdrawal scores were associated with poorer psychological health.

5. *Psychological well-being (Harter global self-worth subscale)*. Children's self-perception of psychological well-being was indexed using the global self-worth subscale of the perceived competence scale (Cronbach alpha=0.67; Harter, 1982). This six-item subscale required that children complete six forced-choice format items, selecting which of two bipolar behavioral descriptions were "really true or sort of true of you." Sample items included, "Some kids like the kind of person they are" versus "other kids often wish they were someone else," and "Some kids are often unhappy with themselves" versus "other kids are pretty pleased with themselves." Higher scores indicated better perceptions of psychological well-being, associated with better psychological health.

*Chronic physiological stress*. Crowding (and noise) elevate physiological stress in children (Evans, 2001a). Chronic physiological stress data were obtained using three biomarkers of stress and a fourth combined measure of physiological stress: allostatic load. Higher values indicated increased physiological stress for all four variables.

*1. Blood pressure* tracks chronic stress (Krantz & Falconer, 1995). Children's resting blood pressure was recorded by trained researchers using an automated monitor (Critikon Corp., Tampa, FL: Dinamap Model 1846SXP) as the target child sat quietly and read for 25 minutes. After discarding the initial measurement, six additional measurements were taken and averaged to achieve maximum reliability according to previous studies (Kamarck et al., 1992). Parents were asked to keep child participants from engaging in physical activity for one hour before the at-home interview.

*2. Neuroendocrine measures* (cortisol, epinephrine, and norepinephrine) were calculated from 12 hour overnight (8:00 PM - 8:00 AM) total urine samples, kept on ice with a preservative (metabisulfite) and picked up the morning following the at-home interview. Four 10-ml samples were randomly extracted, processed (samples for catecholamine analysis are acidified), and deep frozen at -80° C for subsequent biochemical assays. Epinephrine and norepinephrine were assayed with high-pressure liquid chromatography with electrochemical detection (Riggin & Kissinger, 1977) and free cortisol with a radioimmune assay (Contreras, Hane, & Tyrrell, 1986). Creatine was assayed to provide a statistical control for differences in body mass and incomplete urine voiding (Baum & Grunberg, 1995; Grunberg & Singer, 1990; Tietz, 1976).

*3. Body mass index*[6] was calculated from height and weight measurements recorded by trained researchers (kg/$m^2$) and used to create an index of allostatic load.

4. *Allostatic load*. An allostatic load[7] index was created by summing dichotomized (e.g., 1=within the top quartile of risk, 0=not within top quartile) resting blood pressure (diastolic and systolic); overnight urinary neuroendocrine measures of cortisol, epinephrine, and norepinephrine; and body mass index (McEwen, 1998). Previous studies have used similar procedures to combine multiple physiological indicators into one allostatic load index (Evans, 2003b; Kubzansky, Kawachi, & Sparrow, 1999; Seeman, McEwen, Rowe, & Singer, 2001; Seeman, Singer, Rowe, Horwitz, & McEwen, 1997; Seeman, Singer, Ryff, Love, & Levy-Storms, 2002; Singer & Ryff, 1999).

### *Procedures*

Interior density, crowding, ceiling height, volume, floor plan sketches, psychological health, and physiological stress measures extracted from the original longitudinal data set were initially collected during in-person interviews conducted by pairs of trained research assistants. Participants were informed that the study's purpose was to explore housing and stress. Floor plan sketches were used to calculate depth and permeability, according to

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[6] Body mass index (BMI) = Weight (pounds) / $Height^2$ (inches) x 703 *or* Weight (kilograms) / $Height^2$ (meters). Child BMI was not recalculated using the CDC's more recent recommended procedure for children (CDC, 2011) because it was not expected to affect allostatic load measures used in analysis.
[7] "Allostasis" refers to a dynamic, interactive set of physiological systems of equilibrium maintenance with which the human body continuously adjusts its normal operating range in response to physical and social demands (Evans, 2003b; Ganzel, Morris, & Wethington, 2010; McEwen, 1998; McEwen & Stellar, 1993; Seeman & McEwen, 1996; Sterling & Eyer, 1988). The ongoing maintenance of internal equilibrium increases allostatic load, which reflects chronic wear and tear on the body caused by the mobilization of resources to meet environmental demands (McEwen, 1998).

Hillier and Hanson's procedures (1984), by the author and trained research assistants who had no knowledge of participants' health or physiological stress measures.

*Data analysis*. Pearson product-moment correlation coefficients (Aim 1) and regression procedures (Aims 1 and 2) were conducted using IBM SPSS Statistics for Windows (IBM Corp., Version 20.0). Correlations were first conducted between TCB interior density, TCB crowding, home interior density, and home crowding. Regression models also examined interior density as a predictor of children's self-reported home and bedroom crowding. Then, regression models investigated the interactive effects of crowding (home and TCB) and each design attribute (TCB window area, TCB ceiling height, TCB volume, TCB depth, home depth, and home permeability) on nine outcomes while controlling for the income-to-needs ratio (Table 2.2).

***Table 2.2. Independent and dependent variables***

| Predictors (IVs ) | Outcome variables (DVs) |
|---|---|
| *Crowding (entered separately):*[8] | 1. Psychological health (*Rutter*) |
| 1. TCB crowding | 2. Learned helplessness |
| 2. Home crowding | 3. Psychological distress (*PERI*) |
| *Design attribute (entered separately)*: | 4. Social withdrawal |
| 1. TCB ceiling height (*lowest point*) | 5. Psychological well-being (*Harter global self-worth*) |
| 2. TCB volume | 6. Resting systolic blood pressure |
| 3. TCB window area | 7. Resting diastolic blood pressure |
| 4. TCB depth | 8. Cortisol (*log*) |
| 5. Mean home depth | 9. Epinephrine (*log*) |
| 6. Home permeability | 10. Norepinephrine (*log*) |
| *Interaction term*: crowding x design attribute | 11. Allostatic load (*upper quartile*) |
| *Controls*: income-to-needs ratio | |

## RESULTS

***Aim 1***. Interior density and crowding measures were significantly but not strongly correlated (Table 2.3). Correlation coefficients were nearly equal for comparisons between both TCB interior density and crowding, and home interior density and crowding (r = -0.34 and r = -0.35, respectively). Home interior density was also significantly ($p$<0.01) but not strongly correlated with reports of TCB crowding (r = -0.27). Negative correlation

[8] Regression models including home and TCB interior density were also run for comparison.

coefficients indicated that increases in interior density were, as expected, associated with more child-reported crowding (lower scores). The positive correlation coefficients indicated that TCB and home interior density, as well as crowding measures, were fairly strongly correlated (r = 0.57 and r = 0.55, respectively).

***Table 2.3. Pearson correlations among crowding and interior density measures***

| **Variable** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **1**. TCB interior density | -- | -0.34* | 0.57* | -0.38* |
| **2**. TCB crowding | | -- | -0.27* | 0.55* |
| **3**. Home interior density | | | -- | -0.35* |
| **4**. Home crowding | | | | -- |

* *p*<0.01 TCB = target child's bedroom

Despite lower correlation coefficients, home and TCB interior density did significantly predict children's reported home and TCB crowding (*p*<0.001) when controlling for both income-to-needs ratio and gender (neither income-to-needs or gender were significant; Table 2.4).[9]

***Table 2.4. Regression of children's reported home and TCB crowding on home and TCB interior density after controlling for income-to-needs and gender***

| **Outcome** | **Predictor** | **Total $R^2$** | **$\Delta R^2$** | ***F*** | **d.f.** | ***β****(SE)* | ***P*** |
|---|---|---|---|---|---|---|---|
| Home crowding | Home interior density | 0.14 | 0.10 | 9.39** | 3,176 | -5.30 *(1.20)* | <0.001** |
| | | | | | | | |
| TCB crowding | TCB interior density | 0.14 | 0.11 | 8.33** | 3,159 | -2.04 (*0.47*) | <0.001** |

** = significant (p<0.001)

***Aim 2***. Only regression models including crowding measures (vs. interior density) are reported.[10] Tables 2.5 and 2.6 present results containing significant interactions between crowding and design attributes on children's psychological health and physiological stress, when controlling for income-to-needs. Continuous crowding and design variables were dichotomized for illustrative purposes only (Figures 2.4, 2.5a-h, and 2.6a-g). All regression analyses included the original continuous variables.

[9] When a control for parent-reported crowding was added to home crowding models, home interior density only marginally predicted child's reported home crowding (*p*<0.10). Parent variables were, however, not considered in this study and are not discussed here.
[10] Regression models were also run for interior density and interior density by design attribute interactions (vs. crowding). A summary of significant results can be found in Appendix A.

***Table 2.5. Regression of children's psychological health and physiological stress on the home crowding by design attribute interaction after controlling for income-to-needs***

| **Outcome** | **Moderator** (crowding x design) | **Total $R^2$** | **$\Delta R^2$** | ***F*** | **d.f.** | ***β****(SE)* | ***P*** |
|---|---|---|---|---|---|---|---|
| Allostatic load | TCB window area | 0.132 | 0.102 | 1.980 | 4,52 | 0.000 (*0.000*) | 0.062* |
| BP (resting systolic) | TCB ceiling height (lowest point)[a] | 0.176 | 0.168 | 4.738** | 4,89 | 0.838 (*0.283*) | **0.004**** |
| BP (resting diastolic) | TCB ceiling height (lowest point)[a] | 0.133 | 0.133 | 3.414** | 4,89 | 0.617 *(0.205)* | **0.003**** |
| Epinephrine (log) | TCB ceiling height (lowest point)[a] | 0.098 | 0.097 | 2.492** | 4,92 | 0.018 *(0.008)* | **0.029**** |
| Norepinephrine (log) | TCB ceiling height (lowest point)[a] | 0.179 | 0.173 | 5.008*** | 4,92 | 0.016 *(0.005)* | **0.004**** |
| Allostatic load | TCB ceiling height (lowest point)[a] | 0.156 | 0.126 | 3.733** | 4,81 | 0.093 *(0.044)* | **0.038**** |
| Psychological well-being (Harter global self-worth) | TCB volume[b] | 0.205 | 0.185 | 5.144*** | 4,80 | -0.000 (*0.000*) | **0.004**** |
| Norepinephrine (log) | TCB volume | 0.070 | 0.064 | 1.177 | 4,63 | 4.381E-005 (*0.000*) | 0.090***** |
| Learned helplessness | TCB depth | 0.042 | 0.027 | 1.444 | 4,133 | 0.530 (*0.318*) | 0.098* |

[a] *= main effect of design predictor was also significant (p<0.05)*
[b] *= main effect of crowding was also significant (p<0.05)*
* *= p<0.10 (marginally significant)*
** *= p<0.05 (significant)*
*** *= p<0.001 (significant)*
*TCB = target child's bedroom*

Table 2.5 displays the nine regression models (out of 72) that contained significant interactions between home crowding and TCB window area, ceiling height, volume, and depth on psychological health and physiological stress outcomes, controlling for income-to-needs. Although the interaction between home crowding and *TCB window area* on allostatic load was marginally significant, window area did not buffer the effects of home crowding on allostatic load (Figure 2.4). Increases in crowding were associated with a lower overall allostatic load.

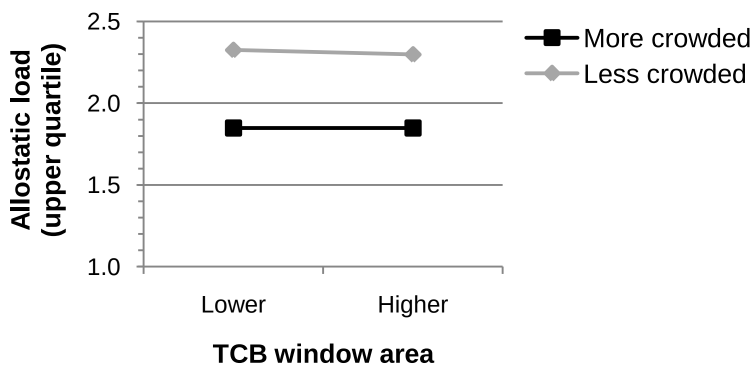



***Figure 2.4.*** *Interaction between home crowding and TCB window area on allostatic load, after controlling for income-to-needs*[11]

Figures 2.5a-h illustrate the remaining significant home crowding by design attribute interactions, controlling for income-to-needs. *TCB ceiling height* buffered the negative effects of crowding as anticipated. Increases in TCB ceiling height were associated with greater decreases in resting systolic and diastolic blood pressure, epinephrine, norepinephrine, and allostatic load among more crowded child participants in the study (Figures 2.5a-e). Among less crowded participants, higher ceiling height was associated with slight decreases in resting diastolic blood pressure, epinephrine, and norepinephrine.[12]

[11] Crowding and design attribute variables were dichotomized (median split) in interaction graphs for descriptive purposes only. Regression analyses of continuous variables were conducted throughout.
[12] Interactions presented in Figures *2.5*a-b were not significant when controlling for body mass index (BMI). Calculations however, used the adult formula [BMI = Weight (pounds) / Height$^2$ (inches) x 703 *or* Weight (kilograms) / Height$^2$ (meters)] and not the CDC's recommended procedure based on 2000 growth charts (Centers for Disease Control and Prevention, 2011).

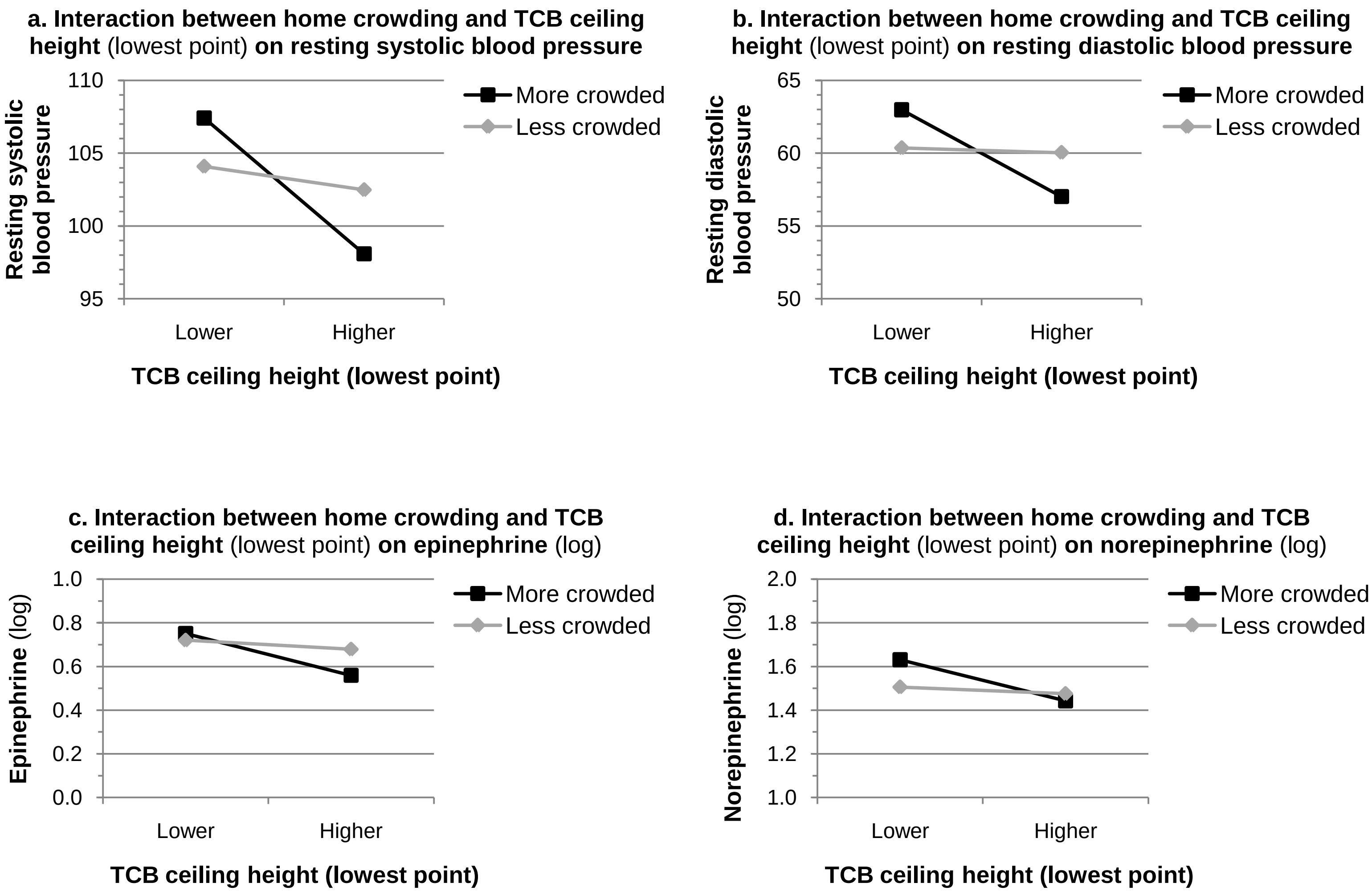
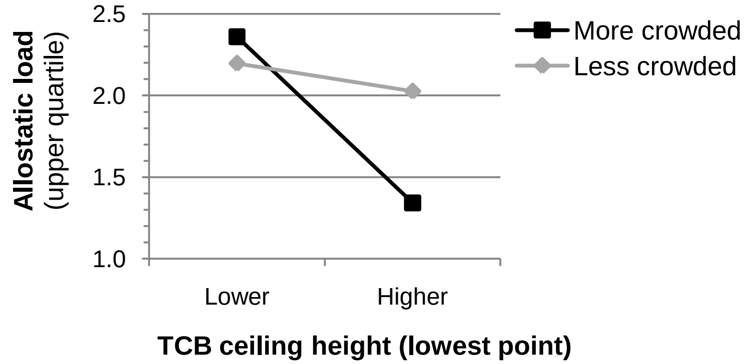



***Figure 2.5.*** *Significant interactions between home crowding and design attributes on psychological health and physiological stress outcomes after controlling for income-to-needs*

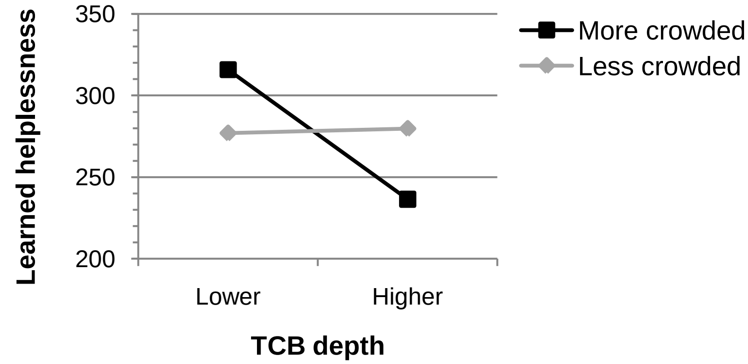
Note: Crowding and design attribute variables were dichotomized (median split) in interaction graphs for descriptive purposes only. Regression analyses of continuous variables were conducted throughout.

*-- (Figure 2.5 continued) --*

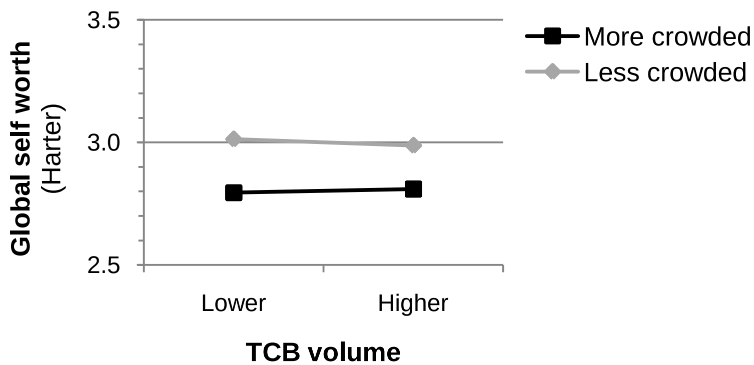
**e. Interaction between home crowding and TCB ceiling height** (lowest point) **on allostatic load** (upper quartile)




**f. Interaction between home crowding and TCB depth on learned helplessness***




**g. Interaction between home crowding and TCB volume on psychological well-being** (Harter global self-worth)*




**h. Interaction between home crowding and TCB volume on norepinephrine** (log)

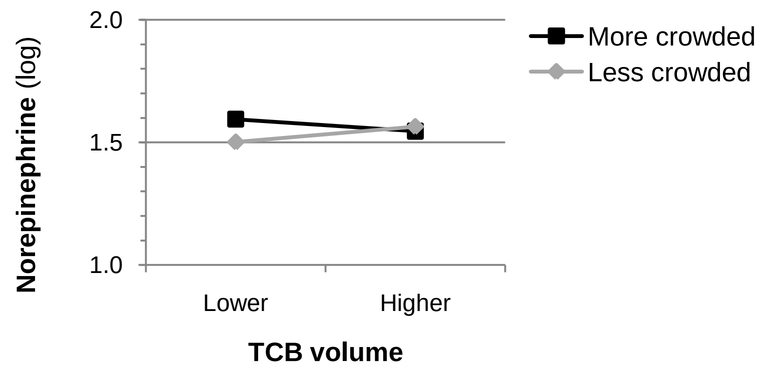



***Figure 2.5.*** *Significant interactions between home crowding and design attributes on psychological health and physiological stress outcomes after controlling for income-to-needs*

** Indicates that lower outcome values in this figure are associated with poorer (vs. better in all other figures) psychological health*

*TCB depth* also moderated the home crowding and learned helplessness relation, but not as expected (Figure 2.5f). Increases in TCB depth were marginally associated with *decreases* in time to persist on a challenging task among more crowded participants. Less crowded participants experienced a very small increase in learned helplessness with an increase in TCB depth. Similarly, *TCB volume* also did not moderate the effects of crowding on perceived psychological well-being as anticipated (Figure 2.5g). Increases in TCB volume were only associated with a slight increase and decrease in Harter global self-worth subscale scores for more and less crowded participants, respectively. Less crowded participants did have higher perceived psychological well-being overall when compared to more crowded participants. *TCB volume*, however, did moderate the negative effects of crowding on norepinephrine according to hypotheses (Figure 2.5h), such that more crowded participants experienced a marginally significant decrease in norepinephrine levels with an increase in TCB volume. Less crowded participants, on the other hand, experienced a slight increase in norepinephrine with an increase in TCB volume.

Table 2.6 summarizes seven (out of 72) regression models that contained significant interaction predictors between *TCB crowding* and TCB ceiling height, TCB depth, mean home depth, and home permeability on learned helplessness, psychological health (Rutter), and resting systolic and diastolic blood pressure, when controlling for income-to-needs. These four design attributes moderated the negative effects of TCB crowding as anticipated, but only among more crowded participants (Figures 2.6a-g).

***Table 2.6. Regression of children's psychological health and physiological stress on the TCB crowding by design attribute interaction after controlling for income-to-needs***

| **Outcome** | **Moderator** (crowding x design) | **Total $R^2$** | **$\Delta R^2$** | ***F*** | **d.f.** | **$\beta$(*SE*)** | ***p*** |
|---|---|---|---|---|---|---|---|
| Learned helplessness | TCB ceiling height (lowest point) | 0.066 | 0.51 | 1.672 | 4,95 | -5.494 *(3.281)* | 0.97* |
| | | | | | | | |
| Psychological health (Rutter) | TCB ceiling height (lowest point) | 0.100 | 0.068 | 3.044** | 4,110 | 0.176 (*0.079*) | **0.027**** |
| | | | | | | | |
| BP (resting diastolic) | TCB depth | 0.071 | 0.071 | 2.381* | 4,125 | 0.020*(0.012)* | 0.101 |
| | | | | | | | |
| BP (resting systolic) | Mean home depth | 0.056 | 0.030 | 1.871 | 4,125 | -0.389 (*0.600*) | **0.048**** |
| | | | | | | | |
| BP (resting diastolic) | Mean home depth[a,b] | 0.091 | 0.091 | 3.119** | 4,125 | 0.699*(0.312)* | **0.027**** |
| | | | | | | | |
| BP (resting systolic) | Home permeability[c] | 0.048 | 0.040 | 1.561 | 4,125 | 3.151*(1.490)* | **0.036**** |
| | | | | | | | |
| BP (resting diastolic) | Home permeability[a,b] | 0.094 | 0.094 | 3.230** | 4,125 | 2.360*(0.993)* | **0.019**** |

[a] *= main effect of design predictor was also significant (p<0.10)*
[b] *= main effect of crowding was also significant (p<0.05)*
[c] *= main effect of crowding was also significant (p<0.10)*
* *= p<0.10 (marginally significant)*
** *= p<0.05 (significant)*
*** *= p<0.001 (significant)*
*TCB = target child's bedroom*

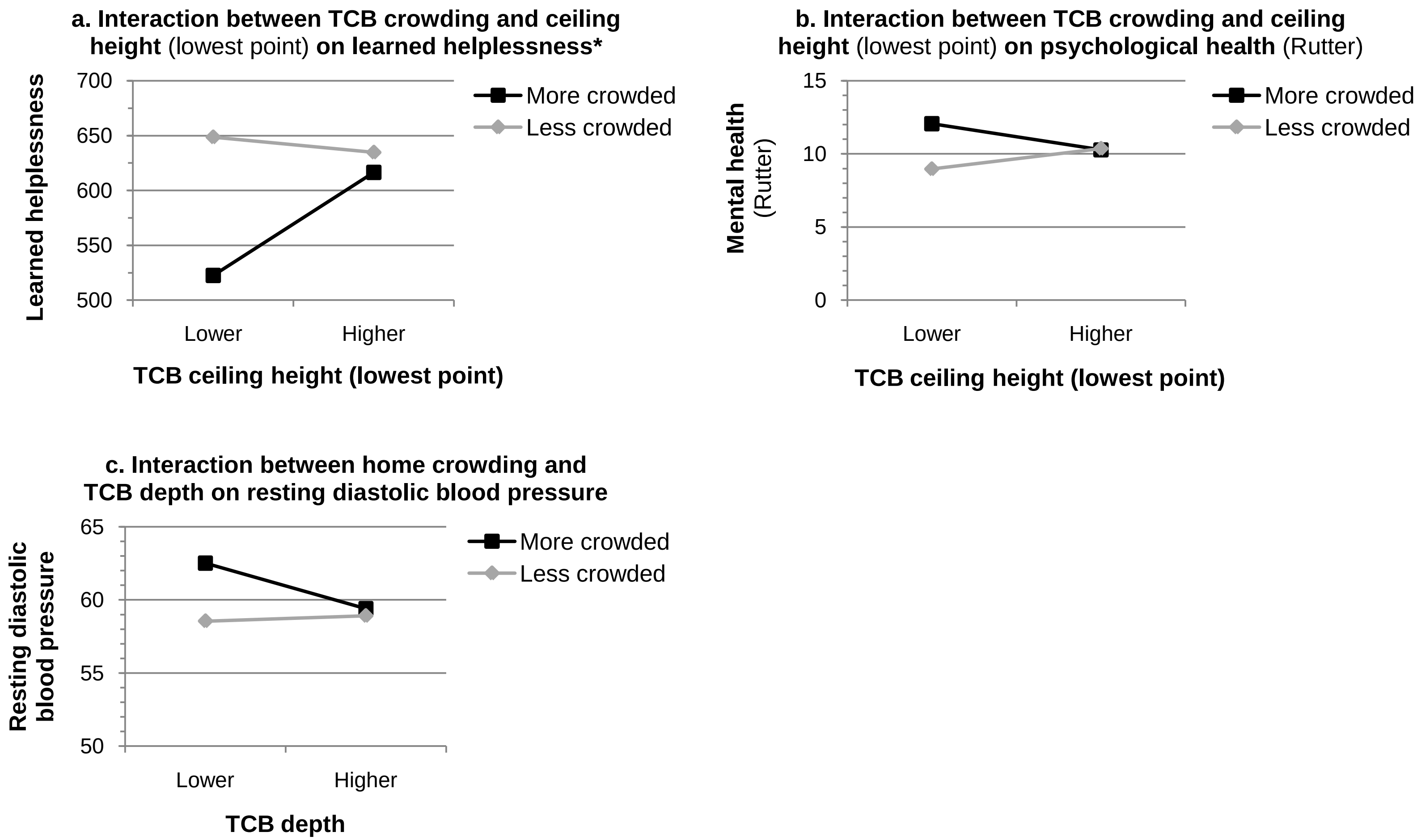



***Figure 2.6.*** *Significant interactions between TCB crowding and design attributes on psychological health and physiological stress outcomes after controlling for income-to-needs*

Note: Crowding and design attribute variables are dichotomized (median split) in interaction graphs for descriptive purposes only. Regression analyses of continuous variables were conducted throughout.

** Indicates that lower outcome values in this figure are associated with poorer (vs. better in all other figures) psychological health*

*-- (Figure 2.6 continued) --*

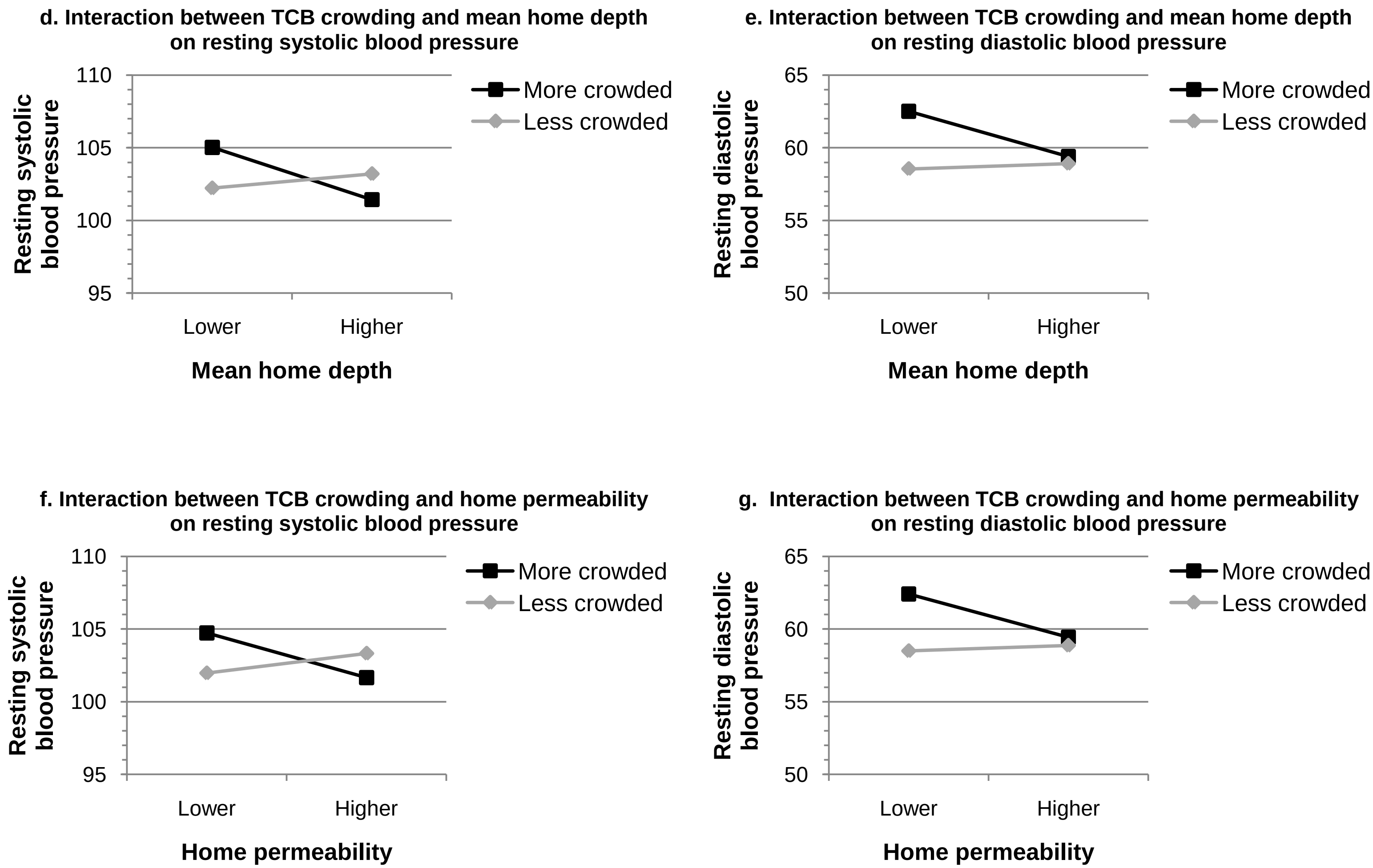



***Figure 2.6.*** *Significant interactions between TCB crowding and design attributes on psychological health and physiological stress outcomes after controlling for income-to-needs*

*TCB ceiling height* appeared to buffer the negative effects of crowding on learned helplessness (Figure 2.6a) and psychological health (Figure 2.6b) among more but not less crowded participants. Higher TCB ceiling height was associated with slightly poorer learned helplessness (marginally significant) and psychological health (significant) scores among less crowded participants. Similarly, *TCB depth*, *mean home depth*, and *home permeability* also buffered the negative effects of crowding on resting diastolic blood pressure among more crowded participants (Figures 2.6c, e, and g). Less crowded participants, however, experienced a negligible increase in resting diastolic blood pressure. *Mean home depth* and *home permeability* also moderated the negative effects of crowding on resting systolic blood pressure (Figures 2.6d and 2.6f). Decreases in resting systolic blood pressure were associated with increases in depth and permeability among more crowded participants, while less crowded participants experienced an increase in resting systolic blood pressure with an increase in home depth and permeability.

## DISCUSSION

This study had two purposes: 1) to examine the relation between residential interior density and children's self-reported crowding and 2) to investigate the potential of design attributes to buffer the adverse effects of crowding on children's psychological health and physiological stress. Results indicated that crowding – rather than interior density – better predicted children's psychological health and physiological stress outcomes within this study sample.[13] This finding suggested that the relation between interior density and crowding may differ among children when compared to adults, and that interior density alone may not be enough to induce adverse effects of crowding among child participants. Other social stressors within and physical characteristics of the home (e.g., parenting, acoustics, window height/treatments, housing quality) also could have influenced the interior density-crowding

[13] Results of main effects analysis revealed that crowding, not interior density, predicted children's psychological health and physiological stress. Therefore, crowding was used in Aim 2 analyses.

relation. Social interaction and privacy may be regulated through both psychological and environmental coping processes (Altman, 1975; Archea, 1977; Evans et al., 1996).

Regression (Aim 2) results only somewhat supported the hypothesis that design attributes moderate the crowding-psychological health and crowding-physiological stress relations among children. TCB ceiling height was the only design attribute that significantly buffered adverse effects of *home crowding* on physiological stress indicators in this study as hypothesized, especially as reported crowding increased (Table 2.5, Figures 2.5a-e). TCB ceiling height also significantly buffered negative effects of *TCB crowding* on children's learned helplessness and psychological health. Children in more crowded bedrooms with higher ceiling heights may have perceived increased personal space and more control over social interactions (Evans et al., 2001; Rodin, 1976). Future work should investigate the role of the entire home's ceiling height, as well as the interactive effects of ceiling height and crowding over time as children age. The association between crowding and psychological health may be stronger for younger children who spend more time inside the home when compared to adolescents (Leventhal & Newman, 2010). A future longitudinal or intervention study would also help establish causality (Evans et al., 1996).

Moderate buffering effects of TCB volume on the home crowding-psychological well-being (Harter global self-worth) and norepinephrine relations among more crowded participants were likely due to differences in ceiling height measures rather than overall volume. Controlling for TCB interior density in volume models, as well as TCB interior density and room size in ceiling height models, could help clarify the role of ceiling height and volume in moderating the effects of home crowding on children.

Similarly, TCB depth, mean home depth, and home permeability significantly buffered the effects of TCB crowding among more crowded participants, but not in the anticipated direction (Figures 2.6c-g). Increases in depth and permeability were expected to buffer the adverse effects of crowding because these types of floor plan arrangements afford desired levels of social interaction (Evans et al., 2000; Lepore et al., 1990). Results, however, did not confirm expectations.

***Strengths***

The present study contributes to the crowding literature in four ways. First, few studies have examined the potential of design attributes to moderate the crowding-psychological health and crowding-physiological stress relations. Second, standardized indices of children's psychological health and physiological stress were used. Outcome variables based on self-reports and observations were accompanied by parent-reported psychological health measures. Physiological stress outcomes were also considered, which have rarely been examined among children (Evans, 2006). Third, this study is one of few that explored the predictive validity of depth and permeability, two space syntax theoretical constructs.

Fourth, this study provided evidence that TCB ceiling height has the potential to buffer adverse effects of crowding and positively affect children's health and well-being, consistent with prior findings among adults (Savinar, 1975). Study results expanded upon findings that suggest children living in crowded homes who can retreat to a space of their own suffer fewer negative effects of crowding (Wachs & Gruen, 1982). The design of that space may also play a role. This is especially critical considering current and future increases in residential interior density, especially among low income populations. Results also supported prior work that suggests the relation between interior density, crowding, and negative outcomes is not linear. At low levels of interior density, the relation is weak and likely dependent upon other psychological, environmental, and situational factors (Gillis, 1979). At higher levels of interior density, the probability of experiencing adverse effects of crowding increases, as well as other factors associated with high interior density influencing discomfort. Intermediate levels of interior density are optimal for psychological health (Gabe & Williams, 1986). For example, in this study participants in less crowded TCBs experienced slight *increases* in blood pressure in homes with higher TCB depth, mean home depth, and permeability (Figures 2.6c-g). Higher depth and permeability may not positively influence children in less crowded homes, but additional research is needed.

### ***Limitations***

This study suffered from threats to internal and external validity that frequent much of the crowding literature. The study was cross-sectional, suffered from selection bias (people choose where they live, or in this case, children's parents chose), and was non-experimental (not a natural experiment, no random assignment to within-persons conditions), therefore no causality could be established. Confounding factors such as length of exposure to high interior density, previous living conditions, parent behavior and well-being, noise, and other stressors in and outside of the home were also not considered (Evans, 2006; Leventhal & Newman, 2010). Furthermore, the association between housing design elements and children's outcomes may vary by individual child characteristics (e.g., age, ethnicity) and over time.

Additionally, a small sample size and low variability among study variables were also limitations. A wider and more representative range of residential interior densities, housing design attributes, and child sociodemographic factors were needed to improve generalizability (Evans, 2003a). Although TCB interior density ranged from 1–4 people per room, home interior density ranged from only 1–1.25 persons per room. Finally, study results were inconsistent with prior work on interior density, crowding, and social withdrawal. Social withdrawal was not a significant predictor in any model, and therefore results did not support social withdrawal as a mediator of the interior density-psychological health relation as found in prior work with adults (e.g., Evans et al., 1996; *see review,* Evans, 2006). Mean home depth also did not moderate the interior density-psychological distress relation among children as in prior studies of adults (Evans et al., 1996). Additional work is needed to examine the effects of social withdrawal and depth on the crowding-psychological health relationship among young children.

### ***Implications and conclusion***

Research indicates that low income populations facing multiple environmental and psychological stressors are most likely to be affected by crowding (Evans & English, 2002; Gillis, 1979; Saegert, 1982). This study demonstrated the potential of an interior design attribute to modify human responses to high interior density. Increasing residential ceiling heights or the perception of ceiling height, versus two-dimensional dimensions, could not only buffer adverse effects of crowding on children, but also potentially reduce overall footprint size and construction costs. Identifying design elements that buffer the adverse effects of crowding is necessary to guide existing high interior density housing renovations and plan future options, especially considering increases in prevalence of high interior density living conditions (Mackun, Wilson, Fischetti, & Goworowska, 2011). Designers are already responding by proposing alternative designs (e.g., Cusato, 2010[14]), but with little or no research on the immediate or long term effects of these alternatives on residents, the economy, or the environment. Empirical evidence establishing design attributes that enable people to cope with higher interior density living conditions would inform designers, investors, and policy makers. This knowledge can guide renovations of existing high interior density housing and inform plans for future developments without introducing additional or worsening existing housing stressors.

[14] A hypothetical home design contains multiple, smaller rooms. The New Economy Home (Cusato et al., 2010) includes an affordable and adaptable small footprint (1771 square feet) with four bedrooms and three-and-a-half bathrooms. The first floor includes a suite and separate entrance that can be rented to generate revenue, utilized by aging parents, or house an older child living at home.

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CHAPTER 3

# OBJECTIVELY QUANTIFYING NEARBY NATURE: LAND COVER DATA AND AUTOMATED GIS PROCEDURES VS. MANUALLY-RATED SATELLITE IMAGES


## ABSTRACT

Although the benefits of nature to human health are well-documented, the "dose" or amount of nature that must be present during exposure to achieve these benefits is unknown. This uncertainty is partially due to the lack of a common and accessible nature measure. The National Land Cover Database (NLCD) and automated Geographic Information Systems (GIS) procedures are often used to estimate amounts of nature within many defined U.S. geographies simultaneously, but the method requires GIS software and experience. NLCD data can also over- or under-estimate amounts of nature depending on urbanity, or population density. Researchers examining health effects of varying levels of nature in dense urban areas are especially challenged by this limitation because small variations in urban vegetation are not captured by NLCD data. To address these limitations, this study developed an alternative nature estimation method using Google Earth satellite images. Estimates of nearby nature surrounding a sample of New York City and central New York State addresses were calculated using the alternative method and then compared to estimates generated from 2006 NLCD data and automated GIS procedures. The inter-rater reliability of the alternative method was 0.996 (Ebel). Comparisons indicated that the alternative method was more appropriate for estimating nearby nature in dense, highly developed urban areas such as New York City (NYC). Within rural and urban areas outside of NYC, however, nearby nature estimates from both methods were fairly strongly correlated, indicating that either estimation method could be used within locations of varying urbanity.

## INTRODUCTION

A substantial body of literature has demonstrated the benefits of nature on various facets of human physical and mental health, cognitive functioning, and well-being (*see review*: Wells & Rollings, 2012). Direct experiences in natural environments, views of nature, and viewing images of nature can positively affect outcomes such as perceived mental health, physical health and well-being; physical activity; self-reported pain; stress recovery; perceived restorativeness; attention and concentration; self-esteem, confidence, and attitude; social interaction; self-discipline; and even job satisfaction (refer to citations in Appendix B, and Wells & Rollings, 2012). Nature exposure can be especially beneficial to residents of dense urban environments where availability of and access to natural areas is limited. However, the "dose" of nature (e.g., Barton & Pretty, 2010) required to obtain the associated physical, mental, cognitive, and social benefits remains unknown. Policy makers, planners, architects, and designers are especially faced with a paucity of research and evidence-based design guidelines that indicate, for example, required square footage of urban park area or the square footage of natural window views needed to benefit residents. Identifying and understanding how doses of nature affect these and other outcomes could not only support further development of theory linking various doses to specific outcomes, but also contribute to policy recommendations and design guidelines concerning nature and nature exposure. In order to establish the "doses" of nature required to achieve benefits and inform professionals, a common nature measurement is needed.

Many studies examining benefits of nature do not measure the amount of nature present in experimental conditions and only broadly distinguish between settings (e.g., participants took a walk in an "urban" and "park" environment). Studies that do attempt to quantify nature suffer from methodological inconsistencies. Measures vary in scale and accuracy (Greenfield, Nowak, & Walton, 2009; Lu & Weng, 2007; Nowak et al., 1996; Walton, 2008; Walton, Nowak, & Greenfield, 2008); indices of nature present are generated from multiple sources of reference data and imagery; and both objective and subjective measures are employed that assess conceptually different attributes of nature: quantity versus quality (*see* Leslie et al., 2010). Although the appropriateness of a measurement method depends on the research question, these methodological inconsistencies hinder comparison across studies and make it difficult to infer any information relevant to dosage. While several digital procedures exist to quantify nature and views of nature, including those using Geographic Information Systems (GIS) and other software packages to analyze satellite images and aerial photos, researchers may not have the necessary funds or experience to utilize the most appropriate method; even with the necessary funds and experience, limitations imposed by each method must be addressed.

The purpose of this study was to contribute to the development of a simplified, accessible, and common nature measurement that facilitates comparison across studies, and that addresses limitations of using National Land Cover Database (NLCD) data in dense urban areas. Two methods for estimating amounts of nearby nature (trees, water, vegetation) surrounding a sample of New York City (NYC) and central New York (NY) State residents were compared: (1) 2006 NLCD data and automated GIS analysis procedures and (2) a proposed, manual, grid-based rating method using Google Earth Satellite images. Development of the proposed, alternative method aimed to address several limitations of using land cover data to estimate nearby nature, offer a nature metric appropriate for dense urban areas, and provide a relatively inexpensive method to quantify nature without GIS software or experience. The first study hypothesis anticipated that manually-rated satellite images would produce nearby nature ratings significantly different from NLCD data estimates. The second hypothesis predicted that any differences in nearby nature estimation methods were moderated by urbanity (population density), such that nearby nature comparisons significantly differed for urban but not rural addresses. Before discussing the current study that compared these two methods, the following sections review methodological inconsistencies in nature measurement as well as limitations of utilizing land cover data to measure amounts of nature.

***Methodological inconsistencies in nature measurements***

<u>*Subjective and objective nature measures*</u>. Methodological inconsistencies in nature measurement impair cross-study comparisons of the link between nature exposure and its various benefits, as well as doses of nature needed to achieve these benefits. The lack of cross-study comparison may be due to the different attributes of natural areas actually assessed by the various *subjective* and *objective* methodologies employed in these studies (Leslie et al., 2010). Self-reported, perceived, *subjective* levels of nature measure nearby nature from a *participant's point-of-view at ground-level*. Perceptions, however, may be influenced by other factors such as perceived access and safety (Jones, Hillsdon, & Coombes, 2009). While subjective measures reflect *quality* of green space, *objective* measures of nature address *quantity* of green space (Leslie et al., 2010; Sugiyama, Francis, Middleton, Owen, & Giles-Corti, 2010), which are more relevant within the context of nature exposure dosage. Measuring amounts of and proximity to nearby natural areas using GIS and land cover data or aerial imagery, for example, yields an objective measure based on the amount of nature visible from an *above-ground viewpoint*. Objective measures of nature generated from above-ground data are valuable because they are more accessible practically and financially than ground-level measures; above-ground data also facilitate measurement of large geographic areas and sample sizes when used with GIS. Objective measures are also relevant in determining required dosages of nature exposure. Despite these advantages, studies objectively measuring amounts of and proximity to nature calculated using aerial data fail to distinguish between attractive natural settings that encourage use from uninviting, inaccessible, or unused natural settings (Leslie et al., 2010; Sugiyama et al., 2010). Actual usage of or exposure to natural areas by study populations is not typically assessed. Although the current study does not assess participants' actual exposure to or perceptions of natural areas, it focuses on developing an accessible, objective, and quantitative metric to measure amount of nature present that could then later be supplemented with these additional measures.

*Inconsistencies in objective nature measures.* In order to survey inconsistencies in objective nature measurement, a literature search was conducted during the spring of 2010 using the Web of Science database and Google Scholar to identify studies on the benefits of nature exposure that attempted to objectively define or measure nature in some way (e.g., count number of trees, measure proximity to natural areas, or calculate percentage of green space). Results yielded just 32 articles discussing 36 studies that examined the beneficial effects of direct nature exposure, views of nature, or viewing images of nature on various physical, mental, and cognitive outcomes (see Appendix B). Studies focusing on tree cover were excluded (Nowak et al., 1996). Of the 36 studies, 11 exposed participants to nature via images or videos, six via window views of nature, six via direct exposure (e.g., outdoor walk or run), one via both direct exposure and window views, and five via public open and green space observation. The other seven large scale epidemiological studies examined various health outcomes based on calculated percentages of green space surrounding participants' homes. Only 11 of the 36 studies measured amounts of or proximity to natural features, which is necessary to study amounts of nature needed to obtain associated benefits. One study measured the number and proximity of trees to buildings in public spaces. Another seven studies compared exposure to various rated levels of nature. Ratings were based on four- or five-point scales (amount of tree cover and grass; natural and built areas; natural view), categories of nature based on either presence or absence of natural elements (flowers, trees, animals), or rural and urban status. Fifteen of the remaining 17 studies contained a control group that compared broadly defined natural (nature, trees, park, arboretum, outdoors, or camping) and control conditions (urban, blank wall, built elements, or brick wall) with no quantification of the amount or lack of nature. These 36 studies highlight the methodological inconsistencies in nature measurement and need for a common quantification of nature.

***Limitations of using land cover data to measure nearby nature***

Land cover data and GIS or similar software procedures are frequently used methods to quantify natural areas (e.g., de Vries et al., 2003; Ellaway et al., 2005; Maas, de Vries, et al., 2009; Maas, Verheij, et al., 2006). The 2006 National Land Cover Database (NLCD), based on circa 2006 Landsat Enhanced Thematic Mapper+ satellite data, applies a 16-class land cover classification scheme across the conterminous U.S. at a spatial resolution of 30 meters (Fry et al., 2011). The free, easily accessible data are often used to assess natural resources, impervious land cover, tree canopy and other vegetation, and related environmental and health outcomes. Advanced classification techniques have improved NLCD accuracy (Lu & Weng, 2007); however, three limitations of using this data must be considered and are described in Table 3.1.

***Table 3.1. Limitations of using land cover data to measure nearby nature***

| **Limitation** | **Description** |
|---|---|
| *1. Software expertise* | Researchers must have or pay someone with analysis software experience, which makes land cover data less accessible or financially impractical for small samples. |
| *2. Scale & resolution* | Differences in geographic extent must be considered when comparing land cover data sources (Greenfield et al., 2009). Comparison area extents must be the same in each data set to avoid over- or under-estimating land cover in one of the data sets. Natural area estimates using NLCD 30m land cover data are useful for larger geographic areas (e.g., 1km and 3km residential areas; Maas, de Vries, et al., 2009; Maas, Verheij, et al., 2006), but not for estimating nature near a residence (e.g. Wells, 2000; Wells & Evans, 2003; Kuo, 2001; Kuo & Sullivan, 2001; Kuo, Sullivan, & Wiley, 1998). Larger resolution imagery containing smaller grid cells produce more accurate estimates for this application, but require more time (Nowak et al., 1996). Digital, high-resolution files are also large and time-consuming to manipulate (Walton et al., 2008). |
| *3. Accuracy* | Preliminary error estimates of NLCD impervious cover ranged from 4 to 17% (Homer et al., 2007; MRLC, 2009). Results of one accuracy assessment comparing estimates from 2001 NLCD data and Google Earth imagery for randomly sampled and dispersed locations across the U.S. indicated that NLCD consistently underestimated impervious (non-natural) cover across the U.S. by 5.7% within cities and villages, and 1.3% in counties. The degree of estimation, however, varied by population density class (Greenfield et al., 2009). Another study expanded this assessment to include the entire conterminous U.S. and further test differences between estimates generated from 2001 NLCD and Google Earth imagery. Results revealed that NLCD significantly underestimated impervious cover in 44 of 65 mapping zones by an average of 1.4%, and by as much as 5.7% in one mapping zone. Although several accuracy assessments have been conducted (e.g., Foody, 2002; Greenfield et al., 2009; Nowak & Greenfield, 2010), comparisons of land cover data and other data sources to complete accuracy assessments suffer from these same limitations and must be conducted and interpreted with caution (Foody, 2002). |

Understanding the limitations of NLCD data can result in better application of the data (Nowak & Greenfield, 2010). Two of these three limitations especially occur in urban areas, where land cover data often fail to convey changes in vegetation patterns due to image resolution and building shadows (Greenfield et al., 2009; Lu & Weng, 2007; Nowak & Greenfield, 2010; O'Neil-Dunne, 2008).

*NLCD accuracy and image resolution in urban areas.* Depending on image resolution, the error for estimated amounts of greenness varies, especially in dense urban areas (O'Neil-Dunne, 2008). Researchers examining dense urban populations cannot assess varying levels of nature surrounding participant residences when all locations fall within the same land cover classification (e.g., developed, high intensity). Measuring nearby nature in these highly-developed urban areas is especially challenging, partially due to land cover image resolution. The 30m spatial resolution of the land cover raster images is too big to distinguish between varying levels of nature within developed 30m x 30m land cover grid cells. For example, with the exception of large parks, NYC is primarily classified as developed, but the percentage of “green” present varies widely throughout the city. These variations are not captured by land cover data primarily because of what are known as “mixed pixels.” Most land cover classification approaches are based on “per-pixel” information (e.g., each 30m grid cell in the NLCD land cover data is a pixel), where each pixel is assigned only one land-cover classification value. Variations in landscapes, however, and the spatial resolution of remotely-sensed imagery result in “mixed pixels” or grid cells containing multiple land cover types (Lu & Weng, 2007). Each cell’s classification is based on the land cover type that is most common within that cell, but ignores other types and results in reduced land cover data accuracy (see example, Figure 3.1). Mixed pixels lead to over-estimation of nature in areas with pixels containing mostly natural land cover classification types and under-estimation in areas with pixels containing less nature within each cell (Lu & Weng, 2007; Nowak et al., 1996).

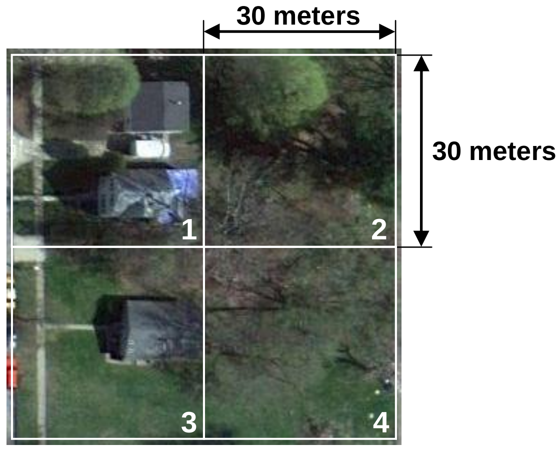


***Figure 3.1**. Mixed pixel illustration*

*The 30 meter resolution grid above is superimposed over a high resolution Google Earth aerial image. Pixels 2 and 4 are homogenous, undeveloped, forested areas. Pixels 1 and 3 are "mixed pixels" that contain vegetation, built structures, and paved areas. Pixel 1 would be considered developed because the structures and paved areas cover the majority of the pixel. Pixel 3, however, contains a smaller structure than Pixel 1, but would also be considered low intensity development. In both pixels 1 and 3, trees, grass, and other vegetation is ignored.*

*Land cover data accuracy and building shadows in urban areas.* Measuring nearby nature in highly-developed urban areas is also challenging because of shadows cast by tall, densely sited buildings. Land cover data frequently underestimate nature in urban areas (Greenfield et al., 2009; Lu & Weng, 2007; Nowak & Greenfield, 2010; O'Neil-Dunne, 2008). This underestimation is problematic when focusing on benefits of nature exposure at smaller scales, and in areas primarily classified by one type of land cover such as dense urban areas. Urban building shadows referred to as "urban canyons" can contribute to the underestimation of nature by land cover data in urban areas (O'Neil-Dunne, 2008). Trees and other vegetation are hidden in these shadows and not included in land cover or tree canopy classifications. This limitation, however, applies to all aerial imagery and remotely-sensed data. Continuous improvements in land cover data technology, such as the use of LiDAR (Laser Imaging Detection and Ranging) to improve tree canopy estimates in NYC (O'Neil-Dunne, 2008), will assist with improving accuracy of land cover data sets.

***Current study***

Satellite imagery from sources such as Google Earth have been used when land cover data are incomplete or do not exist, to supplement available land cover data, and to assess the accuracy of land cover data (Cha & Park, 2007; Nowak & Greenfield, 2010; Wickham, Stehman, Fry, Smith, & Homer, 2010). Google Earth (Google Inc., 2011) is a free downloadable software program that displays virtually mapped satellite imagery and aerial photography of the Earth's surface. The program also supports geospatial data through Keyhole Markup Language (KML). Google Earth imagery provides one of the best data sources to assess overall land cover because it nearly covers the entire conterminous U.S. with interpretable images (Nowak & Greenfield, 2010). To address limitations of using land cover data in urban areas to estimate nearby nature, and to explore a potential common nature metric, the current study compared nearby nature estimates generated from both NLCD and Google Earth satellite imagery, as well as how estimates differed by the moderating factor of urbanity. The study is described in the following sections.

## METHODS

### *Addresses*

Estimates of nearby nature were calculated for a total of 321 residential addresses in central NY and NYC (Figure 3.2). Central NY addresses were gathered from 239 participants in a housing study primarily in the Finger Lakes Region, and 82 NYC residents participating in a study related to chronic pain. At the U.S. census block group level, 139 study addresses were categorized as rural (non-farm and farm areas), 100 addresses were classified as urbanized areas and urban clusters outside of NYC, and 82 addresses were within NYC urbanized areas (refer to *Constructs and Measures*).

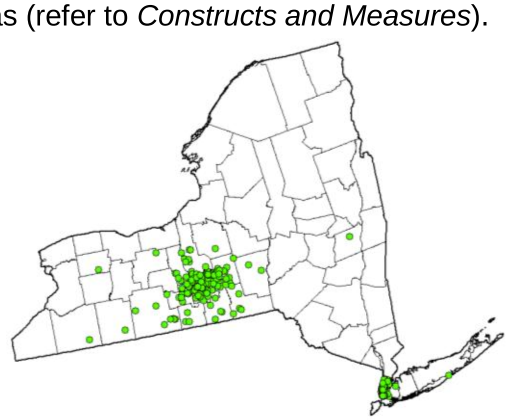

***Figure 3.****2. Residential address locations in New York State*

### *Research Design*

The dependent variable in this cross-sectional study was nearby nature. The type of estimation method used to generate estimates (percentages) of nearby nature was the independent variable. Estimates were generated using two methods: (1) automated GIS procedures with 2006 NLCD data and (2) manually-rated Google Earth satellite images. Comparisons of estimates generated by each method were first conducted for all addresses. Because differences in nearby nature estimates were expected to vary by population density, urbanity served as a moderator of the estimation method and nearby nature estimate relationship (Figure 3.3).

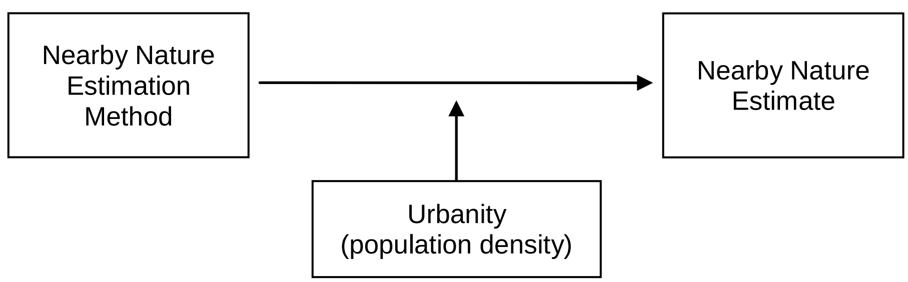


***Figure 3.3**. Research design for the comparison of nearby nature estimation methods*

### *Constructs and Measures*

*Nearby nature*. Nearby nature was defined as the percentage of trees, grass, vegetation, and water surrounding each address within a square measuring 840m or approximately ½ mile per side. Estimates of nearby nature were calculated using NLCD data and Google Earth satellite images as described in the *Procedures* section.

*Urbanity (population density)*. To examine whether differences in nature estimation methods are moderated by varying population densities, or urbanity, in rural and urban locations each typically containing more homogeneous to more heterogeneous land cover types, respectively (Greenfield et al., 2009; Walton et al., 2008), addresses were separated into three groups based on U.S. census definitions of rural, urbanized areas (UA), and urban clusters (UC).[15] Using U.S. census classifications of only “urban” and “rural” to dichotomously categorize study addresses created an urban category containing addresses from both small cities (e.g., Ithaca, NY with a city population of ~30,000 and metropolitan area population of ~100,000) and densely-developed NYC (city population 8,000,000, metropolitan area population 18.9 million). The wide variation in population density and nearby nature at these locations suggested that three rather than two categories were appropriate for analyses. Therefore, to distinguish between these widely varying urban densities, UA block groups within NYC were separated from addresses within UAs and UCs outside of NYC (Figure 3.4).

| | **Nearby Nature Estimation Method** | |
|---|---|---|
| **Nearby Nature Estimate Comparisons** | **2006 NLCD** | **Google Earth Satellite Images** |
| 1. All addresses | 321 addresses | 321 addresses |
| **Urbanity (moderator):** | | |
| 2. Rural (non-farm and farm areas) | 139 addresses | 139 addresses |
| 3. Non-NYC UA+UC | 100 addresses | 100 addresses |
| 4. NYC UA | 82 addresses | 82 addresses |

***UA = Urbanized area UC = Urban cluster***

***Figure 3.4****. Sample distribution for the comparison of nearby nature estimation methods*

### *Procedures*

ArcMap (ESRI ArcMap 10.0, 1999-2010), a GIS software package, was used to geocode participant addresses and digitally create two sets of concentric squares, centered on each address point. Each of the smaller squares’ sides measured 840m (~1/2 mile), or 420m (~1/4 mile and 14 of the 30m land cover grid cells) from the square’s center point. Address points and corresponding squares in compatible formats were superimposed over

[15] U.S. Census Bureau definitions: *Urbanized areas* (UA)= Cores of metropolitan statistical areas (e.g., NYC) that contain populations >50,000 people. UAs consist of contiguous census block groups with population densities of ≥1,000 people/mile$^2$ (390 people/km$^2$), and surrounding census block group densities of ≥500 people/mi$^2$. *Urban clusters* (UC)= Cores of micropolitan statistical areas (e.g., Cortland, NY) with total populations of <50,000 people. *Rural*= Areas not considered UAs or UCs are classified as *rural* and contain <2,500 inhabitants outside of an UA. Geographic areas outside of metropolitan areas (e.g., census tracts, counties) are often partly classified as both urban and rural. In the census sample data products (not 100% data), such as those used in this study, rural areas are further classified into rural farm and rural non-farm areas. Rural farm areas include households and housing units on farms, while rural non-farm areas include all remaining rural population and housing units (U.S. Census Bureau, 2000). In this study, rural farm and rural non-farm areas were both considered “rural.”

both NLCD data (Figure 3.5a) and Google Earth satellite images (Figure 3.5b). Another set of 6480m (~4 mile) per-side squares was also generated for reasons discussed in the *Data analyses: part 2* section.

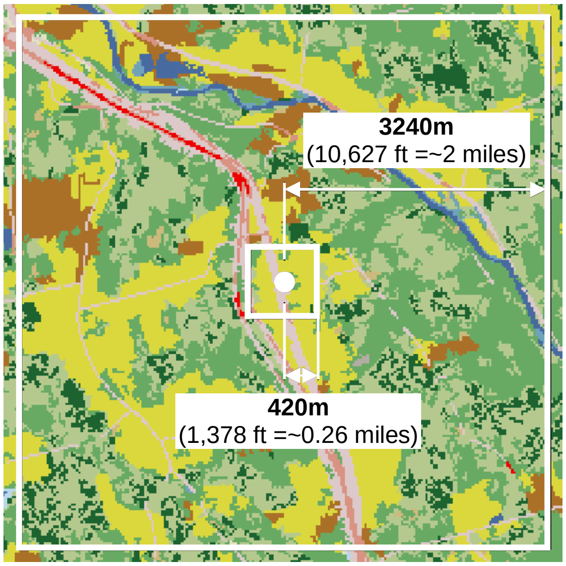


***Figure 3.5a.*** *840m (~1/2 mile) & 6480m (~4 mile) squares overlaid on NLCD grid*


***Figure 3.5b****.* *840m (~1/2 mile) & 6480m (~4 mile) squares centered on Google Earth satellite image*

Squares, instead of circles, were used in order to better capture full NLCD cells and pixels when overlaying polygons on the NLCD grid.  Furthermore, the ¼-mile square "radius" was selected because ¼-mile is conceptually relevant when examining the benefits of nature exposure.  Although this distance varies empirically, some studies indicate that people are more likely to walk to destinations such as transit, shopping, and eating located 10 to 15 minutes away from home (Frank, Anderson, & Schmid, 2004; O'Sullivan & Morrall, 1996; Seneviratne, 1985; Vuori, Oja, & Paronen, 1994).  Thus, the assumption made is that people are more likely to be exposed to nature located within this distance from their residence.  Estimates of nearby nature proximate to each address point were then objectively calculated using 1) NLCD data and automated GIS procedures and 2) manually-rated Google Earth satellite images:

*1) NLCD data and automated GIS procedures*.  Cell counts for each land cover classification within all ½-mile squares were extracted in the U.S. Geologic Survey USA Contiguous Albers Equal Area Conic projected coordinate system using Geospatial Modeling Environment (GME; Beyer, 2011) tools.[16]  Overall percentage of nearby nature[17] in each square was then calculated by dividing the sum of natural classification cell counts by the total cell count in each ½-mile square.

*2) Google Earth*.  Trained research assistants opened converted, Google Earth-compatible, geocoded address point and digital square files in Google Earth.  Next, they created an image of each address and surrounding square by first fixing the view altitude to 650m,[18] then copying and pasting the satellite image into a 7" x 7" table template generated in a word processing program.  Images were carefully cropped to the ½-mile square border,

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[16] GME is an open source software platform that facilitates and often simplifies spatial analysis and modeling tools (Beyer, 2011).

[17] "Natural" NLCD classification categories in this study: 11. Open water, 21. Developed, open space, 31. Barren land (rock/sand/clay), 41. Deciduous forest, 42. Evergreen forest, 43. Mixed forest, 52. Shrub/scrub, 71. Grassland/herbaceous, 81. Pasture/hay, 82. Cultivated crops, 90. Woody wetlands, and 95. Emergent herbaceous wetlands.  The following NLCD classifications were not considered natural: 12. Perennial ice/snow, 22. Developed, low intensity, 23. Developed, medium intensity, and 24. Developed, high intensity.

[18] This distance was chosen because it fit the image to the computer screen.  It was important to fix the distance so the image extent remained the same on computer screens of various sizes.

labeled, and printed. Nearby nature estimates were calculated by manually estimating the percentage (0, 10, 25, 50, 75, 90, or 100%) of nature within each overlaid 1" grid square, summing all percentages, and dividing by 49 (the total number of 1" squares within the overlaid grid).[19] Roof gardens, swimming pools, and construction sites were not considered "natural." All address points fell within high-resolution, interpretable satellite images captured between 2007-2011. Three images contained difficult-to-interpret areas due to shadows and were individually enlarged and brightened to assist with nature estimation.

*Data analyses: part 1*. IBM SPSS Statistics (Version 19) was used to examine whether significant differences existed between the two methods of estimating nearby nature. Paired t-tests were conducted and Pearson product-moment correlation coefficients were calculated for 1) all addresses (hypothesis 1). Three additional comparisons among 2) rural, 3) non-NYC urbanized areas and urban cluster addresses, and 4) NYC urbanized area addresses were conducted to examine whether any differences in nearby nature estimates varied by urbanity (hypothesis 2).

*Data analyses: part 2*. Because 2006 NLCD data and Google Earth satellite images (2007-2011)[20] were generated at different times, NLCD data procedures were repeated with 2001 and 2006 NLCD data, and 1/2-mile (840m) and 4 mile (6480m) squares (Figures 3.5a and 3.5b). Paired t-tests and Pearson product-moment correlation coefficients were calculated for 2001 and 2006 nearby nature estimates. Significant results would suggest that any differences found in nearby nature estimation methods resulted from changes in land cover over time, not differences between NLCD and Google Earth data. Therefore, these additional tests were conducted to rule out this alternative explanation.

[19] The inter-rater reliability (Ebel) of this measure was based on three trained raters' estimations of nearby nature for 10 urban (Ebel=0.99), 10 suburban (Ebel=0.95), and 10 rural (Ebel=0.96) addresses. The overall inter-rater reliability (Ebel) among the four trained research assistants who worked on this study was 0.996. Because of the high inter-rater reliability, study images were each rated by only one trained rater.
[20] Google Earth added dates to their imagery after this analysis was completed.

## RESULTS

***Table 3.2.*** *Comparison of 2006 NLCD and Google Earth satellite image nearby nature estimates (percentages) within 840m (~1/2 mile) squares*

| ***Distance*** | ***Type, Data Set (Date)*** | | ***M (%)*** | ***SD (%)*** | ***t*** | **d.f.** | ***p*** [b] | ***Cohen's d*** [a] *(effect size)* | ***r***$^{2\,b}$ |
|---|---|---|---|---|---|---|---|---|---|
| **840m (~1/2 mile)** *(420m or ~1/4 mile from address)* | **Hypothesis 1: Differences in nearby nature estimates** | | | | | | | | |
| | **1. All** | Land cover (2006) | 57.39 | 40.38 | -6.85 | 320 | **<0.000** | -0.179 *(-0.089)* | **0.92** |
| | | Sat. images (2007-11) | 63.81 | 30.88 | | | | | |
| | **Hypothesis 2: Urbanity as a moderator** | | | | | | | | |
| | **2. Rural** | Land cover (2006) | 94.15 | 11.94 | 5.76 | 138 | **<0.000** | **0.380** *(0.187)* | **0.75** |
| | | Sat. images (2007-11) | 90.25 | 8.23 | | | | | |
| | **3. Non-NYC UA+UC** | Land cover (2006) | 43.47 | 33.55 | -8.34 | 99 | **<0.000** | **-0.558** *(-0.269)* | **0.85** |
| | | Sat. images (2007-11) | 59.30 | 22.01 | | | | | |
| | **4. NYC UA** | Land cover (2006) | 12.06 | 13.65 | -7.33 | 81 | **<0.000** | **-0.824** *(-0.381)* | **0.49** |
| | | Sat. images, (2007-11) | 24.49 | 16.40 | | | | | |

*Rural = Farm and non-farm  UA = Urbanized area  UC = Urban cluster*

[a] *= Bolded text indicates a small, medium, or large effect. For Cohen's d, an effect size of at least 0.2 can be considered a "small" effect, 0.5 a "medium" effect, and 0.8 to infinity a "large" effect (negative values indicate sat. image estimates > land cover estimates).*

[b] *= Bolded text in column indicates statistical significance at the 0.05 alpha level.*

Data analyses: part 1, hypothesis 1. Paired-sample t-tests, Pearson product-moment correlation coefficients ($r^2$), and effect size (Cohen's d) results are displayed in Table 3.2. As anticipated, significant differences were found in nearby nature estimates generated from 2006 NLCD data and Google Earth satellite images (comparison 1, Table 3.2); however, nearby nature estimates from both methods were strongly correlated with a less than small effect size.

Data analyses: part 1, hypothesis 2. Results of comparisons 2-4 (hypothesis 2, Table 3.2) indicated that urbanity (population density) was a significant moderator of the differences in estimation methods, as hypothesized, such that mean nearby nature estimates from 2006 NLCD data were significantly lower than estimates from Google Earth Satellite images for (3) non-NYC UA and UC and (4) NYC UA comparisons, but not (2) rural comparisons.

Estimates of effect size (Cohen's d) indicated a small effect size for differences in (2) rural nearby nature estimates, a medium effect size for (3) non-NYC UA and UC estimates, and a large effect size for the (4) NYC UA estimates. Nearby nature estimates from 2006 NLCD and manually-rated Google Earth satellite images were strongly correlated for comparisons between (2) rural and (3) non-NYC UA and UC addresses ($r^2$=0.75, 0.85, respectively), but only marginally correlated for NYC UA addresses ($r^2$=0.49). Figure 3.6 further demonstrates how differences in nearby nature estimates generated from the two estimation methods varied by urban NYC, non-NYC urban, and rural classifications.

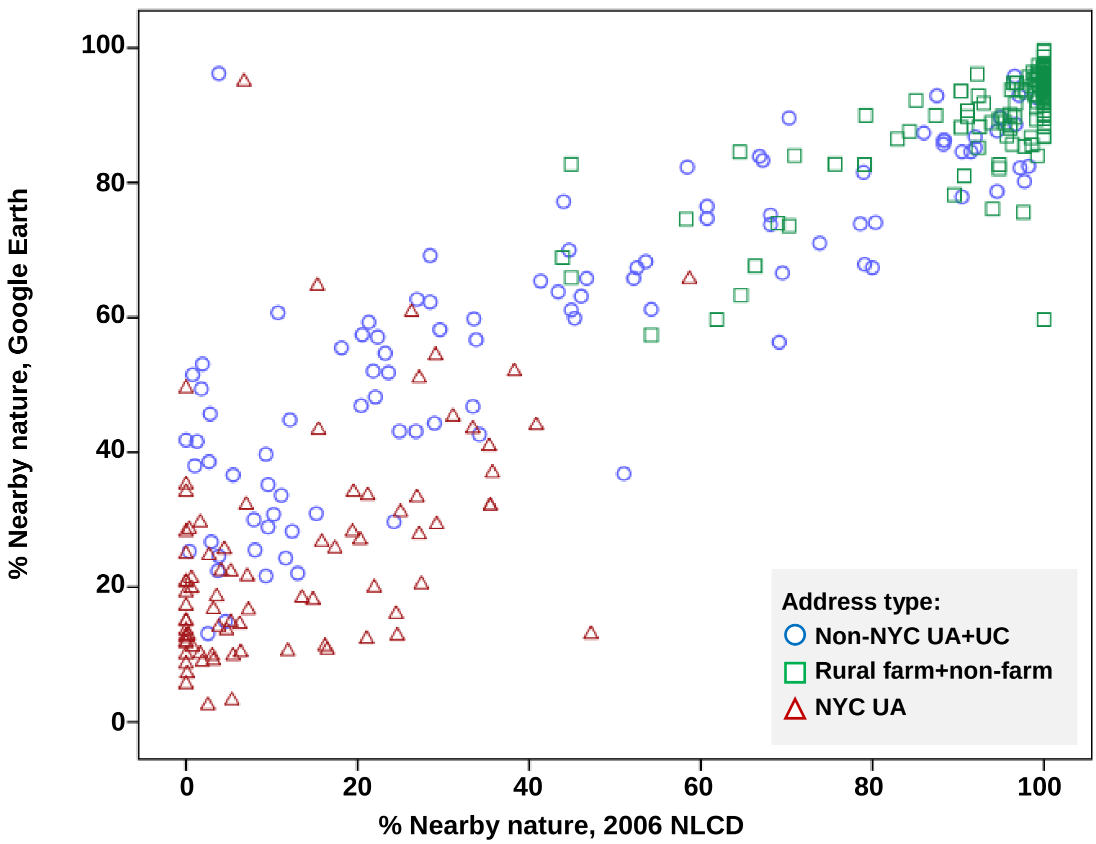


***Figure 3.6.*** *2006 NLCD vs. Google Earth satellite image nearby nature estimates (percentages) within 840m (~1/2 mile) squares*

<u>*Data analyses: part 2*</u>. Because Google Earth satellite images (2007-2011) and 2006 NLCD data were generated during different time periods, additional paired-sample

t-tests and correlations were conducted using 2001 and 2006 NLCD land cover data sets.[21] These comparisons explored whether land cover within 840m (~1/2 mile) and 6480m (~4 mile) squares significantly changed over time. Any significant variations in land cover over time (e.g., an increase in impervious land cover and a decrease in amount of vegetation), instead of estimation method could account for significant differences in nearby nature estimates and serve as an alternative explanation. Results of these comparisons are displayed in Table 3.3 and Figures 3.7 and 3.8.

***Table 3.3**. Comparison of 2006 and 2001 NLCD nearby nature estimates (percentages) within 840m (~1/2 mile) and 6480m (~4 miles) squares*

| *Distance* | *Type, Data Set (Date)* | | *M (%)* | *SD (%)* | *t* | d.f | *p* [b] | *Cohen's d* [a] (effect size) | $r^2$ [b] |
|---|---|---|---|---|---|---|---|---|---|
| **840 m** (~1/2 mile square centered on address) | **Hypothesis 1: Differences in nearby nature estimates** | | | | | | | | |
| | **1. All** | Land cover (2006) | 57.39 | 40.38 | -4.33 | 320 | **< 0.001** | -0.003 *(-0.002)* | **1.00** |
| | | Land cover (2001) | 57.52 | 40.40 | | | | | |
| | **Hypothesis 2: Hypothesis 2: Urbanity as a moderator** | | | | | | | | |
| | **2. Rural** | Land cover (2006) | 94.15 | 11.94 | -3.37 | 138 | **=0.003** | -0.007 *(-0.004)* | **1.00** |
| | | Land cover (2001) | 94.23 | 11.82 | | | | | |
| | **3. Non-NYC UA+UC** | Land cover (2006) | 43.45 | 33.55 | -3.37 | 99 | **= 0.001** | -0.008 *(-0.004)* | **1.00** |
| | | Land cover (2001) | 43.75 | 33.66 | | | | | |
| | **4. NYC UA** | Land cover (2006) | 12.06 | 13.65 | -0.85 | 81 | =0.40 | -0.008 *(-0.004)* | **1.00** |
| | | Land cover (2001) | 12.07 | 13.64 | | | | | |
| **6480m** (~4-mile square centered on address) | **Hypothesis 1: Differences in nearby nature estimates** | | | | | | | | |
| | **1. All** | Land cover (2006) | 74.61 | 29.66 | -8.05 | 320 | **<0.001** | -0.005 | **1.00** |
| | | Land cover (2001) | 74.74 | 29.69 | | | | *(-0.002)* | |
| | **Hypothesis 2: Hypothesis 2: Urbanity as a moderator** | | | | | | | | |
| | **2. Rural** | Land cover (2006) | 97.98 | 3.34 | -3.90 | 138 | **<0.001** | -0.012 | **1.00** |
| | | Land cover (2001) | 98.02 | 3.29 | | | | *(-0.006)* | |
| | **3. Non-NYC UA+UC** | Land cover (2006) | 80.78 | 10.49 | -11.17 | 99 | **<0.001** | -0.04 *(-0.019)* | **1.00** |
| | | Land cover (2001) | 81.18 | 10.27 | | | | | |
| | **4. NYC UA** | Land cover (2006) | 27.46 | 9.33 | 1.62 | 81 | =0.11 | 0.004 *(0.002)* | **1.00** |
| | | Land cover (2001) | 27.42 | 9.31 | | | | | |

*Rural = Farm and non-farm UA = Urbanized area UC = Urban cluster*

[a] *= For Cohen's d, an effect size of at least 0.2 can be considered a "small" effect, 0.5 a "medium" effect, and 0.8 to infinity a "large" effect (negative values indicate 2001 estimates > 2006 estimates).*

[b] *= Bolded text in column indicates statistical significance at the 0.05 alpha level.*

[21] More recent NLCD data are not yet available.

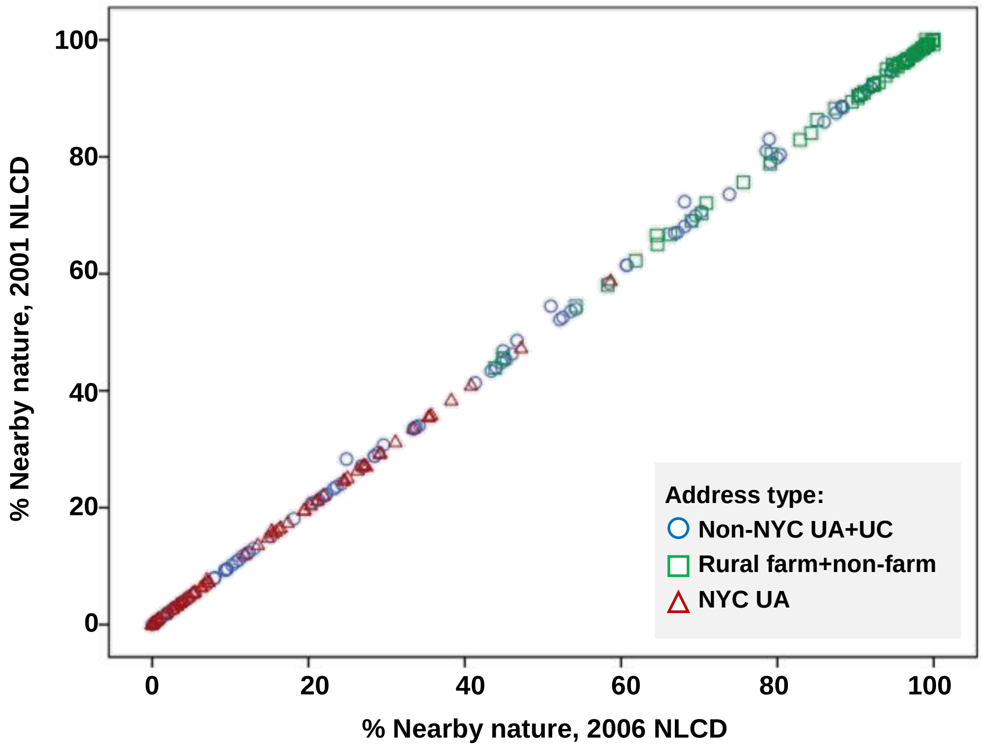


***Figure 3.7.*** *2001 vs. 2006 NLCD nearby nature estimates (%) within 840m (~1/2 mile) squares*

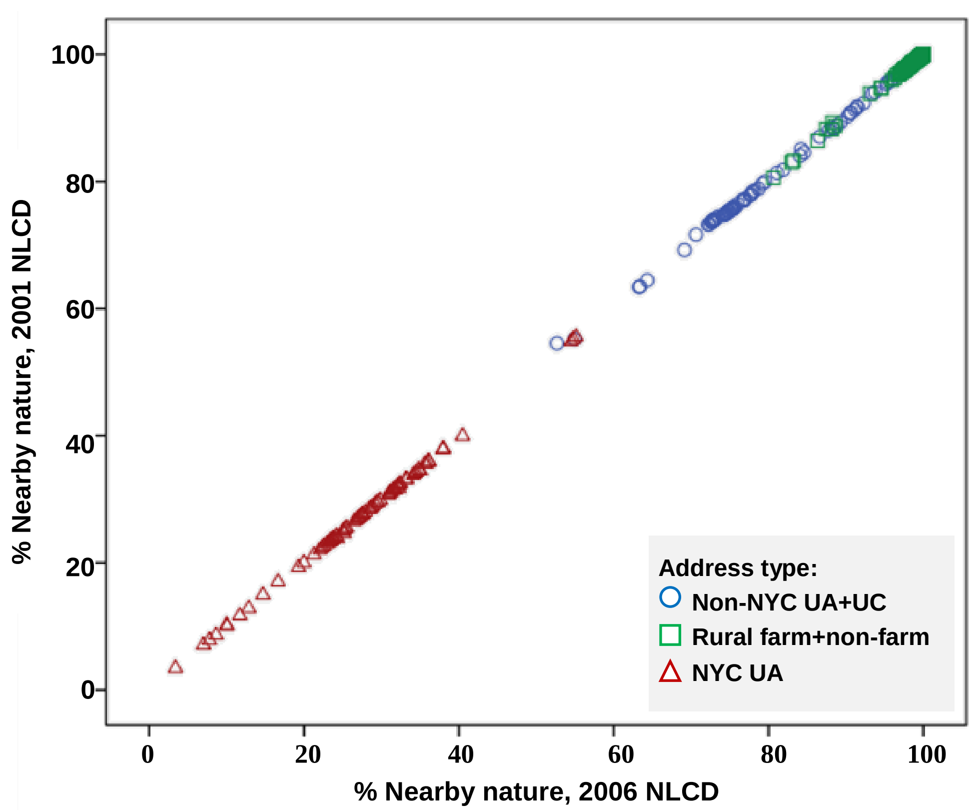


***Figure 3.8.*** *2001 vs. 2006 NLCD nearby nature estimates (%) within 6480m (~4 mile) squares*

Although results from the (1) overall, (2) rural, and (3) non-NYC UA and UC estimates were significant at the 0.05 alpha level for both 840m (1/2 mile) and 6480m (4 mile) squares, extremely small effect sizes (Cohen's d < 0.05) and mean nearby nature estimate differences of less than one percent indicated that changes in land cover between 2001 and 2006 NLCD data were minimal. Figures 3.7 and 3.8 further demonstrate the nearly perfect correlations between nearby nature estimates generated by each data set at two scales.

## DISCUSSION

### ***Results***

*Hypothesis 1.* Results of the comparison conducted among 2006 NLCD- and Google Earth-derived nearby nature estimates for (1) all addresses revealed significant differences in nearby nature estimates generated from each method as hypothesized; however, nearby nature estimates were strongly correlated and the effect size was less than small. These differences may have resulted from errors in manual satellite image rating, error in NLCD data, or minor variations in land cover over time, in addition to differences in estimation method. Because nearby nature estimates from both methods were strongly correlated with a less than small effect size, either method could be used to estimate nearby nature when exploring locations of varying levels of urbanity.

*Hypothesis 2.* Results of comparisons among rural, non-NYC UA and UC, and NYC UA nature estimates revealed significant differences in (2) rural estimates, but the effect size was small and the correlation coefficient was relatively high ($r^2$=0.75). Land cover in rural areas tends to be homogeneous, and large areas of "green" tend to be overestimated by NLCD data, as well as photo-interpretation methods (Greenfield et al., 2009; Lu & Weng, 2007; Nowak & Greenfield, 2010; Nowak et al., 1996; Walton et al., 2008). The overestimation of large areas of nature likely accounted for the higher average nearby nature estimate (94% vs. 90%). Estimates of nearby nature surrounding the (3) non-NYC UA and UC addresses were most strongly correlated ($r^2$=0.85), but there was a medium effect size of estimation method indicating that nature in more densely developed areas was perhaps underestimated by NLCD. NYC UA estimates (4) were the least correlated ($r^2$=0.49) and the effect of estimation method was high, indicating that NLCD, as hypothesized, underestimated nearby nature in dense urban areas. These comparisons suggest that the proposed method using manually-rated Google Earth satellite images is more appropriate for estimating nearby nature in highly developed urban areas such as NYC. However, since nearby nature estimates from both methods were fairly strongly correlated for rural and non-NYC UA and UC addresses, the Google Earth satellite image estimation method offers an alternative method for researchers lacking GIS and NLCD data analysis experience.

*Data analyses: part 2*. Nearby nature estimates from 2006 and 2001 NLCD data for locations in this study were highly correlated, varied by less than one percent over time, and did not significantly differ. Any change in development immediately surrounding addresses (~1/2 mile square) and within a broader area (~4 mile square) was minimal. Although Google Earth images were from 2007-2011, this suggests that changes in vegetation and development over time were not a likely explanation for significant differences found between nature estimation methods. Time lags between imagery dates have been found to have little influence on land cover estimate comparisons (Wickham et al., 2010). Instead, differences can be attributed to underestimation of nearby nature in urban areas by NLCD data. The “mixed pixel” issue previously discussed most likely accounted for significant differences in nearby nature estimation methods. Each NLCD grid cell’s classification is based on the land cover type that is most common within that cell, but other types are ignored resulting in over-estimation of nature in areas with pixels containing mostly natural land cover classification types (e.g., rural areas) and under-estimation in areas with pixels containing less nature (e.g., urban) within each cell (Lu & Weng, 2007; Nowak et al., 1996).

### *Strengths*

This study addressed limitations of using NLCD data in especially urban areas to assess nearby nature. The proposed Google Earth estimation method better accounts for "mixed pixels" (Lu & Weng, 2007) in all areas, whereas land cover data does not, making the grid-based rating method a valuable alternative when studying nature in especially urban areas. The freely available Google Earth method can also quickly be learned and completed without GIS software. Instead of using GIS to geocode addresses and create square boundaries, the extent of a Google Earth window can be fixed. Or, specifically-sized square boundaries of interest can be created and superimposed using other software, or by manually measuring and drawing over the image based on map scales.

### *Limitations*

Although the alternative Google Earth estimation image method addressed several limitations of using NLCD data to estimate nearby nature, there were five possible limitations of the Google Earth method. First, errors in image interpretation may have been present even though inter-rater reliability of training image estimates was high. Second, any incorrectly geocoded addresses would introduce additional error to the manually-calculated nearby nature estimates. Additionally, any error in positional accuracy (Nowak & Greenfield, 2010) of Google Earth imagery would also contribute error to manual estimates; however, Google Earth was only used to estimate the proportion of nearby nature within each square in this study, and not to assess the accuracy of individual NLCD grid cells. Fourth, the "mixed pixel" phenomenon could have occurred during completion of manually-rated satellite images. Grid cells containing large areas of nature (e.g., rural addresses) may have been overestimated while those containing many small amounts of nature may have been underestimated (e.g., urban addresses). Finally, the Google Earth estimation method may not be appropriate for large samples. It requires training and rating each address individually,[22] rather than the automated GIS procedures used with NLCD data. Other study

[22] Approximately 10 images were rated per one hour, after completing 30 training images.

limitations to consider included generalizability, the use of tree canopy data and two- versus three-dimensional imagery, and quantity versus quality of natural areas.

*Generalizability*. The small and non-random sample of address locations limits the generalizability of study results. Additionally, differences in nearby nature estimates may not be as evident in other parts of the country, as underestimation by NLCD data tends to be greatest in the eastern and most urbanized part of the United States (Nowak, Walton, Dwyer, Kaya, & Myeong, 2005). Estimates should be calculated and compared using both methods for addresses in additional locations throughout the U.S. to test the proposed manually-rated image method and plausibility of using the proposed method as a common nature measurement. Furthermore, although research has found that variations in creation dates of land cover data do not influence comparisons of land cover estimates, and negligible changes in landscape over time were found in this study, changes in landscape over time could still be problematic when assessing nearby nature in areas experiencing significant development.

*Tree canopy and two- versus three-dimensional imagery*. Data analysis only included 2001 and 2006 NLCD land cover data, but not tree canopy. Tree canopy data are only available from 2001. Additionally, ground-level vegetation and tree canopy were not separated in Google Earth satellite images. All nearby nature estimates in this study were generated from aerial, two-dimensional images, but three-dimensional, ground-level views of nature may have greatly varied. Using these estimation methods, an area of entirely grass was assigned the same value as an area covered by both grass and tree canopy. Exposure to a flat field of grass verses a field of both grass and trees may be associated with different benefits and required dosages. This distinction should be considered when using these methods to assess nearby nature and nature dosages.

*Quantity versus quality of natural areas*. Estimation methods in this study focused on quantity of natural areas, but did not distinguish between addresses surrounded by a single large natural area and addresses surrounded by multiple smaller areas of green (i.e., is exposure to a higher number or total area of nature more beneficial?). Moreover, estimation methods only captured quantity of nature and not quality – attractiveness, available facilities, other attributes – of natural areas likely to affect actual usage and exposure to nature. It is important to note that the presence of natural areas, including parks, alone may not be enough to encourage use. The types of opportunities afforded by these spaces (i.e., facilities), such as walking and bike trails, safety, trees, shade, play equipment, water fountains and bathroom facilities, athletic fields, paved and grassy areas, etc., may attract park users. Parents and children, for example, may visit parks that are not necessarily nearby their residence to visit with friends, or to use specific facilities supporting particular activities (Potwarka, Kaczynski, & Flack, 2008). While these objective measurements based on aerial imagery can begin to provide evidence suggesting dosage, ground-level objective observations using, for example, Google Street View are needed in addition to quantitative measures to address these limitations.

***Implications and Future Research***

The proposed nearby nature estimation method using Google Earth imagery addresses limitations of NLCD data, especially in urban areas. The Google Earth method has the potential to provide researchers with an inexpensive tool to quantify amounts of nearby nature without GIS when examining cognitive, social, and physiological benefits of nature with relatively small samples, facilitating the development of a common metric that supports cross-study comparisons and exploration of required nature dosages. Additionally, the Google Earth method could potentially be applied to ground-level imagery and window views, addressing additional limitations of using aerial imagery, and to quantify amounts of nature present, test dosage, and generate dosage recommendations.

The variability of underestimation of nearby nature estimates by NLCD relative to satellite photo-interpretation must be understood given the increased use of NLCD products in planning, environmental resource management, and large-scale epidemiological studies (Nowak & Greenfield, 2010). Using additional sources of data, such as Google Earth satellite imagery, to address this limitation is promising but further research is required. Future studies are needed to test the proposed Google Earth method in other locations across the U.S. and to apply it to other types of nature exposure, such as window views, views of natural imagery, and ground-level views. In addition to developing a common quantitative measure of nature, future research might assess whether views of nature versus time spent in nature have an impact; how nearby nature estimates from two- versus three-dimensional imagery relate to actual nature exposure; and how much time spent in nature and what level of engagement yields what outcome. Perceptions of nature should also be accounted for as they may also affect dosage. Procedures to assess ground-level nature could be explored using Google Street view, for example, to compare assessments of two- versus three-dimensional estimates of nearby nature. Furthermore, supplementing quantitative nature measures with the use of a global positioning system (GPS) to measure participants' actual exposure to nature may provide more accurate objective information relevant to determining dosage.

A common measurement is needed to facilitate comparison, compilation, and sharing of research findings and empirical data across disciplines and professions (Ong, 2003). Policy makers, planners, architects, and designers are especially faced with a paucity of research and evidence-based design guidelines that indicate, for example, required square footage of urban park area or the square footage of natural window views needed to benefit residents. Identifying and understanding how doses of nature affect these and other outcomes could not only support further development of theory linking various doses to specific outcomes, but also contribute to policy recommendations and design guidelines for nature and nature exposure.

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CHAPTER 4

# CAFETERIA ASSESSMENT FOR ELEMENTARY SCHOOLS (CAFES): INSTRUMENT DEVELOPMENT


## ABSTRACT

With data from 50 low-income elementary schools and 2,000 National School Lunch Program participants in four states, the Cafeteria Assessment for Elementary Schools (CAFES) tool was developed to quantify physical attributes of cafeteria environments at four scales: room, table, plate, and food. CAFES offers a valid, reliable, and objective tool to assess the need for and effectiveness of environmental interventions based in environmental psychology and behavioral economics strategies linked to selection and consumption of fruits and vegetables (FV). Reliability (KR-21) of the overall instrument and four scales was 0.88 (overall), 0.80 (room), 0.72 (table), 0.83 (plate), and 0.58 (food). Subscales within the room scale included ambient environment, appearance, fenestration, layout and visibility, advertising and signage, and kitchen and serving area. Table scale subscales consisted of furniture, availability, display layout and presentation, serving method, and variety. FV serving and consumption data, obtained from lunch tray photography, were used to validate CAFES. Multi-level modeling indicated that plate scale scores predicted total and side dish FV served. The table scale was directly associated with side dish FV consumed. Total CAFES and all four scale scores were associated with percentage consumed of side dish FV served. The four scale scores also significantly predicted the percentage consumed of total FV served. By identifying environmental attributes associated with healthy eating at four environmental scales, CAFES can be used to identify critical areas for intervention; suggest low- and no-cost intervention strategies; and contribute to guidelines for cafeteria design, food presentation and layout, and cafeteria operations aimed at promoting and increasing FV consumption among elementary school students.

## INTRODUCTION

Rates of childhood obesity have more than tripled in the past 30 years, reaching epidemic levels in the United States and other countries. Among U.S. children ages 6-11, the prevalence of obesity increased from 6.5% to 19.6% between 1980 and 2008 (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010). Increased attention to the obesity crisis has revealed the importance of the environment in encouraging or discouraging healthful behaviors (Evans, Wells, & Schamberg, 2010; Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003; Sallis, Bauman, & Pratt, 1998; Wells, Ashdown, Davies, Cowett, & Yang, 2007). Because both dietary intake and physical activity patterns established early in life likely influence long-term health (Kelder, Perry, Klepp, & Lytle, 1994), understanding environmental influences on children's health behaviors, especially in schools, is critical. More than 97% of U.S. children five years and older typically spend six to eight hours per day for nine to ten months, or 1300 hours per year, in school buildings (Institute of Medicine, 2007; Jones, Brener, & McManus, 2003). Children also consume as many as two meals and snacks per day while at school (Story, Kaphingst, & French, 2006), accounting for 19-50% of their daily caloric intake (Gleason & Suitor, 2001). Considering that federally-funded breakfast and lunch programs feed millions of students daily, school cafeterias have great potential to encourage healthy eating.

This paper discusses the development of the Cafeteria Assessment for Elementary Schools (CAFES) tool, the first observation-based instrument that quantifies elements at the scales of room, table, plate, and individual food item within elementary school cafeterias. With a focus explicitly on elementary school cafeteria environments, CAFES measures attributes of the physical environment linked to children's selection and consumption of healthier foods. Prior research on environmental influences and dietary intake primarily focuses on macroscale factors (*see reviews*: Galvez, Pearl, & Yen, 2010; Singh, Slahpush, & Kogan, 2010; Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008), yet many food decisions, particularly for young children, occur at the microscale. The following sections outline sources of elementary school food, present behavioral economics and environmental psychology concepts relevant to eating, review literature on influences of physical environment on healthy eating, and finally discuss the current CAFES development study.

***Elementary school food sources***

*National School Breakfast and Lunch Programs*. School meals are available primarily through federally-funded School Breakfast and Lunch Programs that provide schools with financial aid to offer students affordable meals and snacks. Free and reduced price meals (FRPM), in addition to full price meals, are offered to students based on need. In the U.S., nearly 99 percent of public schools participate in USDA breakfast and lunch programs (Story et al., 2006). The National School Lunch Program (NSLP) serves more than 31 million students per day (USDA, 2012). Federally-subsidized school meals must meet the Dietary Guidelines for Americans (USDA & USDHHS, 2010); however, U.S. food and agricultural policies, economics, and politics have made high calorie, low-nutrition foods and commodities in increasingly larger portion sizes more affordable to schools (Levine, 2008). Schools rely on students purchasing federal school meals to obtain subsidies, but financial struggles encourage schools to also offer competitive foods (including fast food) for additional revenue (Levine, 2008; U.S. General Accounting Office, 2005). As a result, meals and actual student consumption often fail to meet the Dietary Guidelines for Americans, including recommended consumption of fruits and vegetables (M. K. Fox, 2010; Kimmons, Gillespie, Seymour, Serdula, & Blanck, 2009).

*Competitive foods*. Competitive foods are all foods other than federal school meal items offered for sale in schools from vending machines, snack bars, concession stands, school stores, fundraisers, and a la carte options (S. Fox, Meinen, Pesik, Landis, & Remington, 2005). Although these foods are typically less available in elementary schools than middle and high schools (French & Stables, 2003), they still compete with healthier and often more expensive meal options. Certain competitive foods regulated by the USDA, such as soft drinks and candies, cannot be sold during meal times where federal meals are served (Food Research and Action Center, 2004); but, these competitive foods can be offered elsewhere in the school at any time, including in vending machines just outside the cafeteria (Story et al., 2006; Wildey et al., 2000). Schools are also permitted to sell other competitive foods not regulated by the USDA, such as potato chips, ice cream, candy bars, and baked goods, to students in any location at any time, including in cafeterias and during meals (Story et al., 2006).[23] While federal school meal programs regulate nutritional value and portion sizes of NSLP meals, neither meals brought from home nor competitive food and beverage options, including vending machine items, are required to follow the Dietary Guidelines for Americans (Story et al., 2006; Story et al., 2008; USDA & USDHHS, 2010; U.S. General Accounting Office, 2004).

*Fruit and vegetable intake*. Despite the well-documented health benefits of fruit and vegetable consumption (Baranowski et al., 2000; Kelder et al., 1994; Van Duyn & Pivonka, 2000), approximately 80% of U.S. school-aged children, especially low-income youth, fail to meet national dietary guidelines for fruit and vegetable intake (Lorson, Melgar-Quinonez, & Taylor, 2009). Consumption of fruit, vegetables, and milk is highly correlated with the quality of students' diets (Lino, Gerrior, Basiotis, & Anand, 1999; Marlette, Templeton, & Panemangalore, 2005). Yet, during school lunches, several studies have found that fruits and vegetables (FV) are thrown away more than any other food item (Bark, 1998; Reger, O'Neil, Nicklas, Myers, & Berenson, 1996; St Pierre et al., 1992); among school children, 40% of cooked vegetables, 30% of salads, and 20% of fruits are wasted daily (Guthrie & Buzby, 2002). Research indicates that school-based environmental interventions have the potential to affect health behaviors, including increasing students' FV consumption (*see reviews*: French & Stables, 2003; Blanchette & Brug, 2005; Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008; Wells et al., 2007). Strategies that promote healthy choices and

[23] Because elementary school students are not permitted to go off campus during meal times, off-campus food options do not rival cafeteria lunches.

encourage FV consumption among young children not only also reduce FV plate waste, but set students on positive, healthy life course trajectories (Wethington, 2005).

***Behavioral economics and environmental psychology***

Elementary school students may not have the maturity to consider the long term health effects of their food selections when facing the immediate appeal of sugary, high-fat, and high-sodium foods in cafeteria lines (Mancino & Guthrie, 2009). Instead of eliminating unhealthy but often profitable competitive food options, however, school cafeterias can leverage strategies guided by behavioral economics and environmental psychology to encourage participation in federally-funded meal programs, healthier food choices, and consumption of healthy foods while discouraging selection of competitive, unhealthy options.

*Behavioral economics* examines the psychological, social, and physical factors that influence students' behavior, including healthy food choices and consumption in school cafeterias (Just, Mancino, & Wansink, 2007; Mancino & Guthrie, 2009). Stress and distraction associated with long lines and short meal times can lead students to make unhealthy and impulsive food selections (Mancino & Guthrie, 2009). Within the context of school cafeterias, factors such as the design, display, layout, preparation, and pricing of food items can affect food choices when students face these stresses and distractions (Mancino & Guthrie, 2009; Thaler & Sunstein, 2008). For example, placing a salad bar near the cash register, using a spotlight on an attractive fruit basket placed in a convenient location, and rearranging the order of food items in line have been shown to increase FV purchases in cafeterias when students are offered a choice (*see reviews*: Just et al., 2007, 2008; Mancino & Guthrie, 2009; Chandon & Wansink, 2011). Environmental interventions based in behavioral economics focus on facilitating healthy choices without imposing restrictions on or coercing students. This intervention method is known as "*nudging*" (Mancino & Guthrie, 2009; Thaler & Sunstein, 2008), and is a strategy that contributes to the "small steps" approach to preventing and reducing childhood obesity (Hill, 2009). Rather than focus on weight loss, "small steps" is an alternative strategy that targets childhood obesity by promoting the adoption of small changes in both diet and physical activity that can be sustained over time to prevent further weight gain, and eventually contribute to gradual weight loss (Chandon & Wansink, 2011).

While behavioral economics' nudging strategies focus on *facilitating* students' healthy meal *choices* and *behaviors*, the *environmental psychology* concept of *affordances* describes a group of elements within an environment that presents the opportunity for or allow a particular healthy or unhealthy behavior to occur (Gibson, 1977). Individuals' *perceptions* of affordances influence whether a particular behavior will occur (Alfonzo, 2005). Affordances within the physical cafeteria environment influence eating by serving as either supports that facilitate or barriers that hinder selection and consumption of healthy foods (Sallis & Owen, 2002; Sobal & Wansink, 2007; Story et al., 2006; Wells et al., 2007). Environmental supports within school cafeterias facilitate, promote, foster, encourage, or nudge students to make healthy decisions on their own, and potentially without their knowledge. For example, offering a variety of attractively presented healthy foods increases the appeal and selection of those options. Barriers, on the other hand, hinder health behaviors. A variety of attractive *un*healthy food options competes with healthier options. By considering people's choices, behaviors, perceptions, and motivations, combined behavioral economics- and environmental psychology-based interventions aim to both increase opportunities and supports for healthy eating while simultaneously decreasing barriers related especially to the availability, access (actual or perceived), proximity, convenience, attractiveness, and visibility of food and beverage items within cafeterias. The following section reviews literature on environmental interventions aimed at "nudging" healthy FV servings and consumption while hindering unhealthy choices.

***The physical environment and healthy eating***

Several attributes of elementary school cafeterias that contribute to or "nudge" healthy (and unhealthy) eating affordances have been identified in the literature and further categorized by four conceptual scales: *rooms*, *tables*, *plates*, and *food*. The majority of this work is theoretical, but some empirical evidence does exist linking physical environmental attributes and "nudging" strategies to eating as noted in the following review.

*Room scale*. Behavior settings (Barker, 1968) created within rooms where foods and beverages are consumed, such as cafeterias, contain patterns of and cues for eating. When these cues are more salient within a setting, food and beverage intake can increase due to a lack of cues or affordances that suggest when to stop consumption (Sobal & Wansink, 2007). Within school cafeterias, physical attributes of the kitchen, preparation, serving, and eating areas can potentially affect healthy eating. Although little research has focused on the interaction of school architecture and design with individual health behaviors (Gorman, Lackney, Rollings, & Huang, 2007), existing theoretical and empirical literature on room scale characteristics that affect eating behaviors fall under three general categories: ambient environment and appearance, layout, and advertising and signage.

*-Ambient environment and appearance*. Atmosphere or "ambience" at the room scale can affect cues related to eating (Stroebele & de Castro, 2004). Lighting, fenestration, color, sound, smell, temperature, overall appearance, and other interior design characteristics, in addition to social cues and distractions within a room, can interact to influence food and beverage selection and consumption (Chandon & Wansink, 2011; Sobal & Wansink, 2007; Stroebele & de Castro, 2004). The ambient environment directly and indirectly affects consumption by contributing to diners' comfort and stress levels, and lengthening (or shortening) the desired duration of meals; ambient characteristics may also affect palatability by interacting with sensory perceptions (Sobal & Wansink, 2007). One study found that food consumption increased during cold *temperatures* (Herman, 1993) and when ambient temperatures were outside of the "thermo neutral zone" (Westerterp-Plantenga, van Marken Lichtenbelt, Cilissen, & Top, 2002). Some evidence also suggests that soft, warm, or dim *lighting* increases disinhibition, leading to overeating. The effects of lighting on over-consumption can be further exacerbated when eating with others in restaurants (Wansink, 2004). Although ambient *odors* have been associated with increased

consumption, unpleasant ambient odors have been associated with shorter meal duration and suppressed food consumption (Auvray & Spence, 2008; Rozin, 2009), perhaps by speeding satiation (Chandon & Wansink, 2011). Other evidence suggests that consumption increases with the presence of soft background *music* (Caldwell & Hibbert, 2002; Stroebele & de Castro, 2006). Preferred music can also increase meal time, comfort, and disinhibition (Milliman, 1986). Similarly, unwanted *noise*, such as that from a crowded cafeteria, increases stress and distraction, leading to more impulsive and unhealthy food selection and eating behaviors (Mancino & Guthrie, 2009). The stressful effects of crowding and noise can further be moderated by room size (area, volume), ceiling height, acoustic materials, and the number of students and staff present during a meal time. Furthermore, overall *appearance* contributes to the ambience of the cafeteria environment: fenestration, cleanliness, clutter, and physical condition of the room and furnishings can affect students' stress and comfort levels during a meal (Sobal & Wansink, 2007). Increased stress and discomfort can encourage students to select more convenient, less healthy meal options (Story et al., 2006).

*-Layout (access, convenience, and visibility)*. Inefficient cafeteria layouts, combined with unattractiveness, noise, crowding, short lunch periods, and long lines, can conceptually pressure students to select faster, alternative, less healthy foods and competitive food options (Story et al., 2006). The size, shape, and furniture placement within physical cafeteria floor plans can affect the *accessibility* (actual or perceived) of food and beverages within the room scale via *convenience* and *salience* or visibility (Painter, Wansink, & Hieggelke, 2002; Sobal & Wansink, 2007; Wansink, Painter, & Lee, 2006). Accessibility via convenience has been found to significantly affect children's as well as adults' food intake (Cullen et al., 2003; Wansink, 2004). Floor plan arrangement and design can also conceivably act as a barrier to or support of healthy eating by affecting student circulation. Obstructions (e.g., columns or pillars) may lead students to perceive various food stations as more or less accessible, while efficient cafeteria floor plans can reduce waiting time, line

lengths, prevent staff from being impeded by student traffic, and avoid having students double back or wander in high traffic areas (Gorman et al., 2007). Afforded or available display and preparation space can indirectly affect student consumption if food service staff find preparing and serving fresh, healthy options inconvenient. Layout also influences the visibility of food options. A separate serving room, versus a combined cafeteria and serving space, eliminates visibility of all food items during a meal. A fruit and salad bar in the cafeteria space, however, along with allowing students to obtain second servings, increases visibility of, access to, and convenience of healthy items. Studies found that more visible, proximate, and accessible food options were consumed more frequently and in larger quantities (Engell, Kramer, Malafi, Salomon, & Lesher, 1996; Painter et al., 2002).

Furniture layout, menu location, and trash placement within the floor plan and circulation pattern can also conceivably affect access, visibility, proximity, and convenience. Furniture layout and overcrowding can impede circulation, making it difficult for students to access serving areas and seating. Displaying menus before and outside of the serving line, or offering advanced menu selection (Hanks, Just, & Wansink, 2012), can allow students to preselect their meal choice and reduce impulsive decisions when facing crowded, noisy, and long cafeteria lines (Mancino & Guthrie, 2009). Trash placement, as part of the overall circulation pattern (enter, obtain food, pay, sit and eat, discard waste and return trays, exit), can facilitate better circulation and faster turnover between lunch periods, reducing perceptions of crowding and potentially increasing both perceived and actual access to food stations (Gorman et al., 2007).

*-Advertising and signage*. Some studies have suggested that signage encouraging healthy eating promotes or “prompts” healthy choices, especially when combined with nutrition education and food labeling (French, Jeffery, et al., 2001; Hayne, Moran, & Ford, 2004). Healthy signage, however, must compete with advertising for unhealthful foods children view outside of school (*see review*: Rosenkranz & Dzewaltowski, 2008). Increasing healthy signage and removing unhealthy advertising (commercial beverages, fundraisers

with food, etc.) can prompt children to make healthier decisions in the lunch line and decrease impulsive decision-making (Mancino & Guthrie, 2009; Thaler & Sunstein, 2008).

*Table scale*. Physical attributes within the table scale describe the appearance of surfaces and furniture from which foods and beverages are served and consumed (Sobal & Wansink, 2007). This includes the size, shape, surface material, and condition of tables, counters, and serving displays in a cafeteria. The availability, display and layout, serving method, and variety of items served from cafeteria furniture are additional table scale attributes. Because elementary school students are served food from cafeteria serving area counters and displays, characteristics of the serving area were included in the table scale.[24]

*-Furniture*. The shape, size, and condition of furniture in school cafeteria, serving, and kitchen areas can potentially serve as supports of or barriers to healthy eating (Sobal & Wansink, 2007). Cafeteria table shape may affect consumption indirectly by means of socialization and distraction. Studies among adults found that long, rectangular tables discourage social interaction (sociofugal) while circular tables promote social interaction (sociopetal; Osmond, 1957; Sommer, 1959, 1965). Increased social interaction may distract adults from monitoring consumption and satiety (Birch & Fisher, 2000; de Castro, 1994; Wansink, 2004), but the effect of table shape on children and their eating behaviors is unknown. Additionally, an analysis of the School Nutrition Dietary Assessment Study (SNDA-III) data found that 48% of students complained of a lack of seating in school cafeterias (Mancino & Guthrie, 2009). Furthermore, among elementary students, especially in schools where elementary, middle, and even high school students use the same cafeteria furniture, ergonomic issues may affect students eating behaviors during meal times. Figure 4.1 illustrates small children eating at standard cafeteria tables. The heights of the benches and table surfaces require them to stand while eating. This could conceivably make

[24] Future analysis will consider a serving area “counter scale” separately from the cafeteria table scale. Refer to the discussion section for additional explanation.

consumption more difficult and affect perceived and actual food access, especially when effort such as peeling or cutting is required before consumption.

***Figure 4.1.*** *Smaller students eat lunch while standing at standard cafeteria furniture (photo from di.ncl.ac.uk/publicweb/foodixd_sub/cantoraye.pdf)*

*-Availability and accessibility*. Research highlights the importance of differentiating between availability and accessibility (Swanson, Branscum, & Nakayima, 2009). Availability within the table scale refers to the presence or absence of food items. The presence of a salad bar, for example, was found to increase children's selection and consumption of FV (Slusser, Cumberland, Browdy, Lange, & Neumann, 2007). Accessibility within the table scale, however, relates to whether foods are available in a location and form that facilitates selection and consumption (Blanchette & Brug, 2005; Cullen et al., 2003; Reinaerts, de Nooijer, Candel, & de Vries, 2007). The availability or affordance of healthy options in a school cafeteria alone does not guarantee that items will be selected or consumed unless they are perceived as accessible (Swanson et al., 2009).

*-Display layout and presentation*. Availability of healthy food and beverage options is among the strongest predictors of consumption (Cullen et al., 2003; Story et al., 2008), but carefully planned layouts and attractive food presentation, especially when part of larger health campaigns, can effectively promote NSLP participation and increase or "nudge" selection and consumption of FV (Perry et al., 2004). Clever layouts and presentation increase the perceived access, visibility, and convenience of healthy foods and beverages

by attracting attention (Just, Wansink, Mancino, & Guthrie, 2008; Wansink, 2004; Wansink, Just, & Smith, 2011; Wansink, Smith, & Just, 2010), facilitating healthy choices.

The *layout* or arrangement of food and beverage items on a surface further affects selection of healthy items via proximity, visibility, and convenience. Items within closer proximity or of greater salience within cafeteria lines can encourage or nudge increased selection and consumption (Painter et al., 2002; Wansink, Painter, et al., 2006). One study found that salad bar sales increased when moved in front of checkout stations (Wansink, Smith, et al., 2010). Additionally, locating healthy items at the beginning of the lunch line was associated with an increase in selection of those items. Study results indicated that college students were 11% more likely to select the first rather than third vegetable, and 28% more likely to select a healthier bean burrito when placed ahead of unhealthier tacos in a cafeteria line (Wansink & Just, 2011). Moving plain white milk in front of flavored milk also increased (nudged) the selection of plain milk (Wansink, Smith, et al., 2010). Placing healthy food items first, at eye level, and in multiple or strategic locations in the lunch line increased selection of those items (Thorndike, Sonnenberg, Riis, Barraclough, & Levy, 2012; Wansink, Smith, et al., 2010). Moreover, placing unhealthy options behind the counter, out-of-reach, and accessible by request only decreased selection (Wansink, Smith, et al., 2010). These preliminary empirical results demonstrate linkages between the proximity, visibility, and convenience of food and eating-related external cues to increased healthy and decreased unhealthy item selection and consumption (Chandon & Wansink, 2002; Painter et al., 2002; Sobal & Wansink, 2007, 2008; Wansink, 2004; Wansink & Deshpande, 1994; Wells et al., 2007).

Food display *presentation* can also affect selection. For example, serving fresh fruit from attractive decorative bowls, instead of metal or plastic trays, and serving from a visible, well-lit, convenient location doubled FV intake in one small-scale elementary school study (Wansink, Just, & Smith, 2011). Another study of adults found FV display attractiveness, in addition to menu planning and motivational techniques, increased FV intake by more than

15% (Bandoni, Sarno, & Jaime, 2011). The naming and labeling of items also affects selection. Attractive, creative names (e.g., broccoli bites, tender steamed carrots) versus simple names (broccoli, carrots) increased elementary students' selection of vegetables by 20% (Wansink, Smith, & Just, 2011). Nutrition labeling, as well as signage encouraging healthy eating, promoted healthy food choices when offered with nutrition education on how to read labels among adults (French, Jeffery, et al., 2001; Hayne et al., 2004).

When students are offered meal choices or allowed to serve themselves, the size, shape, and transparency of serving containers can also affect selection and quantity: adults and children serve themselves larger quantities from larger serving containers, plates, glasses, and other utensils (Wansink, 1996; Wansink, Cardello, & North, 2005; Wansink & Cheney, 2005; Wansink & Kim, 2005; Wansink, Painter, & North, 2005; Wansink & Van Ittersum, 2003, 2005; Wansink, Van Ittersum, & Painter, 2006). Organized serving layouts can, on the other hand, lead to smaller serving sizes when compared to cluttered or disorganized patterns (Kahn & Wansink, 2004). Serving items from clear containers, which increases visibility, can also potentially increase selection and consumption. For example, cafeteria ice cream sales decreased when served from a freezer with an opaque lid verses a transparent lid (Wansink, Smith, et al., 2010).

-*Serving method*. School cafeterias affect food serving via serving trays, serving vessels, and food service staff serving items to students. The use of *serving trays* – an affordance - has been associated with the selection and consumption of vegetables among college students (Wansink, Just, & Shimizu, 2011). Because vegetables are often served as a side dish, such as from a salad bar, diners struggle to carry more than a main entrée and beverage container without using a serving tray. Although some all-you-can eat cafeterias have eliminated serving trays in order to reduce plate waste, elementary school cafeterias can encourage salad and other side dish vegetable selection by providing students with serving trays. One study found a 26% decrease in salad selection among college students when trays were not used (Wansink, Just, & Shimizu, 2011). *Serving* *vessel sources* also affect selection quantity. Collective sources, such as bowls or trays, can increase self-serving size when compared to individual, premeasured or pre-plated sources (Sobal & Wansink, 2007). Larger-sized containers and food serving sources can encourage larger self-servings of FV, while smaller containers promote smaller self-servings of unhealthier items when students are allowed to serve themselves. *Food service staff* can also affect students' meal servings. Several serving methods are used in school cafeterias: automatic, offer versus serve, prompt, and self-serve. Using the automatic method, students move through cafeteria lines and are handed items without any choice. Conversely, the "offer versus serve" method, used by more than 75% of elementary schools (Gordon, Crepinsek, Nogales, & Condon, 2007), allows students to decline items automatically being served as part of meal programs that they do not intend to eat, including FV. Instead of allowing students to voluntarily decline meal items, the third food service staff serving method uses verbal prompts (e.g., "Would you like salad?"). Verbal prompts have been associated with increased selection of FV, especially salad (Wansink, Just, & McKendry, 2010; Wansink, Smith, et al., 2010). Alternatively, the fourth "self-serve" serving method allows students to choose and serve themselves meal items, which can increase selection, serving size, and consumption of all foods, as well as plate waste. Access to second servings of FV can also affect overall serving size and consumption (Sobal & Wansink, 2007); however, offering the self-serve option and second helpings for only healthy items can be used to promote selection and consumption of FV.

*-Variety.* Variety, or the number of items and choices offered, has been associated with increased selection and consumption, especially when elementary students were allowed to choose more from at least two items (Just, Lund, & Price, 2012). When students in a laboratory study were asked to choose from two vegetables versus just one, students served a larger quantity of vegetables (Bucher, van der Horst, & Siegrist, 2011). Similar results were found in elementary school cafeterias (Just et al., 2012). A 12% increase in children who consumed at least one serving of FV was found with each additional fruit or

vegetable offered. Another study indicated that the variety of FV offered, rather than the presence or absence of a salad bar, was associated with increased FV consumption (Adams, Pelletier, Zive, & Sallis, 2005). The high variety assortment of different colored foods, such as those offered by a salad bar, likely led to or nudged greater food consumption (Kahn & Wansink, 2004). The increase in complexity and diversity associated with greater variety, such as during a buffet meal, encourages people to consume more (Sobal & Wansink, 2007). Increasing the variety of FV options by, for example, offering a fruit and salad bar, promotes FV consumption; however, offering a variety of competitive foods can also encourage selection of those less healthy options.

*Plate scale*. Plate scale attributes include the next smallest-scale items within cafeterias and include the size, design, shape, color, and material of plates, bowls, glasses, containers, and utensils (Sobal & Wansink, 2007). Adults consume, on average, 71% of their calories from items that have been transferred to a secondary plate or container (Wansink, 1996). The *shape*, *size*, and *transparency* of items at the plate scale can affect how much people serve themselves, such that more is typically consumed from larger or more transparent containers (Wansink, 1996; Wansink, Cardello, et al., 2005; Wansink & Cheney, 2005; Wansink & Kim, 2005; Wansink, Painter, et al., 2005; Wansink & Van Ittersum, 2003, 2005; Wansink, Van Ittersum, et al., 2006). *Food packaging* can also influence adults' consumption via "low fat" labeling (Wansink & Chandon, 2006), but the effects of low fat labeling on elementary students is unknown. Some packaging types create "natural consumption units" (Sobal & Wansink, 2007), that can lead adults to consume an entire package or container to avoid waste, also known as unit bias (Geier, Rozin, & Doros, 2006).

Within elementary school cafeterias where "plates" often take the form of cafeteria *serving trays*, the size, design, and material of students' lunch trays and food containers contribute to the plate scale. Trays can affect the perceived access to food items via convenience. Tray size must be large and the material strong enough to accommodate all meal items, in addition to beverages and utensils.  Flat trays require school cafeterias to use additional serving vessels (plates, bowls, disposable containers, etc.) that are placed on trays.  Trays with built-in compartments, however, reduce or eliminate the need for additional serving vessels that require washing and increase waste if disposable.  Built-in tray compartments also facilitate quicker serving of portions directly on tray surfaces.

Furthermore, not offering students serving trays or tray rests which have been associated with reduced plate waste, can reduce the amount of vegetable sides served and consumed (Wansink, Just, & Shimizu, 2011).  The presence of tray rests along serving stations makes carrying trays and self-serving more convenient or affords convenience, especially for young students.

*Food scale*.  The food scale contains the smallest-scale items of the cafeteria environment and describe the view or appearance (e.g., size, volume, shape, texture, and color) of a particular food or beverage item that will be consumed (French, Story, & Jeffery, 2001; Sobal & Wansink, 2007).  Children often make food choices based on appearance, in addition to taste and convenience (Neumark-Sztainer, Story, Perry, & Casey, 1999). *Appearance* of individual items at the food scale can affect portion size judgment and intake (French, Story, et al., 2001; Sobal & Wansink, 2007), although NSLP meal portions are often controlled by the USDA.  Consumption can also conceptually be associated with the *shape* of foods, such that circular foods are more likely to be fully consumed than square-shaped foods (Krider, Raghubir, & Krishna, 2001).  This has implications for school lunches, especially when foods are served directly into rectangular serving tray compartments or containers.  A “scoop” of mashed potatoes, for example, may be more readily consumed than a spread out, irregular shaped mass in a serving vessel (Sobal & Wansink, 2007). Food *preparation* also affects perceived access and convenience of food items.  For example, fruit consumption can vary depending on whether it is served whole, sliced, or processed.  One study of 6$^{th}$ graders found that whole apples were selected and consumed less than applesauce (Lee, Lee, & Shanklin, 2001; Marlette et al., 2005).  Another study found that serving sliced oranges was associated with an increase in K-4th grade students' orange selection and consumption when compared to whole oranges, with the greatest effect found among younger students; the same results were not, however, found with apples (Swanson et al., 2009).

***Current study***

Although many of the reviewed theoretical links and environmental strategies to promote healthy eating are promising, additional research is needed, especially among elementary school students. Furthermore, the above literature review intentionally excludes three of the most common and successful "nudging" interventions that have been associated with increased FV selection and consumption among middle school, high school, college students, and adults in laboratory settings, college cafeterias, workplace cafeterias, and all-you-can eat buffets. These three strategies - targeting *portion size*, *payment and pricing*, and *choice* - may not apply to many elementary school cafeterias and students, especially with high percentages of FRPM participation. First, the NSLP and other federally-funded meal programs regulate *portion size* and nutrient content. FRPM participants who cannot afford to purchase additional items are limited to consuming only the provided free or reduced-price meal. Second, schools commonly require students to pay for daily school meals, including free and reduced-price meals, with prepaid accounts monitored by meal cards that debit meal costs in daily cafeteria lines (Bland, 2004). Payment and pricing strategies, such as requiring the use of cash to pay for unhealthy items (Just et al., 2008), cannot be used when schools do not allow or require students to carry cash. Furthermore, in schools with 100% of their students receiving free meals, cards are used to track students in lunch lines as no money is exchanged. Unless students can afford to purchase additional items, items are not even priced. Third, not all schools offer students meal *choices*, especially when all students receive a free meal. These factors render many of the most successful behavioral economics- and environmental psychology-based interventions to date inapplicable in elementary schools.

Few elementary school interventions have successfully increased participation in federally-funded meal programs; encouraged selection of healthy options when choices are available; and increased consumption of fruits, vegetables, and other healthy items served. Furthermore, no survey or tool currently exists to assist school staff, researchers, or policy makers in assessing existing physical school cafeteria environments as they relate to diet in elementary schools where young children form health habits that are likely to influence long-term patterns (Kelder et al., 1994). Therefore, this study developed a reliable, valid observer-based instrument to quantify key environmental supports and barriers to healthy eating explicitly in *elementary* school cafeterias across the room, table, plate, and food scales. CAFES scores are intended to direct school staff and researchers to low- and no-cost suggestions for immediate implementation within more macro-level constraints imposed by policy, economics, and geography.[25] The current CAFES development study aimed to answer three questions:

*- 1. What individual attributes of the physical environment should comprise the Cafeteria Assessment for Elementary Schools (CAFES) instrument within room, table, plate, and food scales? Should there be subscales within each of the four scales?*

*- 2. What is the reliability of CAFES and each CAFES subscale?*

*- 3. What is the predictive validity of CAFES?*

The following sections outline the methods and results in response to these three questions.

## METHODS

### *Participants*

School level data were collected from a cross-sectional sample of 50[26] New York, Iowa, Arkansas, and Washington state elementary schools (3,187 students) participating in

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[25] School policies dictate meal time length; federal regulations control NLSP nutrition content, portion sizes, and reimbursement that leads to the need for unregulated competitive food sales; economic policies determine the cost of food; and school location affects available community resources and access to healthy foods.

[26] Although various levels of complete data were obtained from all 50 schools, two schools did not provide enough data to use in scale development and testing (see *Results* section).

a larger U.S. Department of Agriculture (USDA)-funded study.[27] At least 43% of the student population at each school was eligible for free or reduced-price meals. Potential CAFES items were collected from 16 New York and 7 Washington schools by trained researchers, and a subset of items was collected from the remaining 27 schools by Cooperative Extension Educators in Iowa and Arkansas according to written instructions. Student level demographic data[28] and lunch tray photography were gathered from selected 2nd, 4th, and 5th grade classes at each school as part of the larger USDA study. A summary of the 50 recruited schools and student level socio-demographic data used in scale development and reliability testing is displayed in Table 4.1a.

[27] The development of CAFES is part of a larger, 2.5-year, USDA-funded, randomized school garden pilot project that includes examining fruit and vegetable consumption among low-income elementary schools in four states (Wells, N.M., lead researcher). The project team includes Extension Educators from Washington State University Extension, Cornell University Cooperative Extension (NY), Iowa State University Extension and Outreach, and University of Arkansas Extension.
[28] Demographic data, at various levels of completion, was received from 2,158 students.

***Table 4.1a. School and student level socio-demographics***

| | | Total CAFES sample | | | |
|---|---|---|---|---|---|
| **Variable** | ***Data Level*** | **n** | **Variable Levels** | **Total** # | **Total** % |
| **Location** | *School* | 50 | Arkansas | 10 | 20 |
| | | | Iowa | 17 | 34 |
| | | | New York | 16 | 32 |
| | | | Washington | 7 | 14 |
| **Urbanity** | *School* | 50 | Urban | 20 | 40 |
| | | | Rural | 22 | 44 |
| | | | Suburban | 8 | 16 |
| **Gender** | *Student* | 2022 *(3187)* | Male | *930* | 29 |
| | | | Female | *1092* | 34 |
| | | | *Missing* | *1165* | *37* |
| **Free & reduced price meal recipients** | *Student* | 2007 *(3187)* | Full | 662 | 21 |
| | | | Reduced | 198 | 6 |
| | | | Free | 1147 | 36 |
| | | | *Missing* | *1180* | 37 |
| **Grade** | *Student* | 2506 *(3187)* | $2^{nd}$ | 1190 | 38 |
| | | | $4^{th}/5^{th}$ | 1316 | 41 |
| | | | *Missing* | *681* | *21* |
| **Ethnicity** | *Student* | 2033 *(3187)* | White | 1068 | 33.5 |
| | | | Black | 418 | 13.1 |
| | | | Hispanic | 309 | 9.7 |
| | | | Asian | 58 | 1.8 |
| | | | Native American | 28 | 0.9 |
| | | | Other | 152 | 4.8 |
| | | | *Missing* | *1154* | *36.2* |
| **Student population** *(# students)* | *School* | 50 | Mean | | 391 |
| | | | SD | | 168 |
| | | | Range | | 120 – 894 |
| **% Free & reduced price meal recipients** | *School* | 50 | Mean | | 69% |
| | | | SD | | 18% |
| | | | Range | | 43 – 100% |
| **Ethnicity** *(% minority students)* | *School* | 50 | Mean | | 53% |
| | | | SD | | 32% |
| | | | Range | | 1 – 100% |
| **BMI** | *Student* | 982 *(3187)* | Mean | | 19.5 |
| | | | SD | | 5.0 |
| | | | Range | | 10.2 – 46.4 |
| | | | *Missing* | | *2205* |
| **Age** | *Student* | 2060 *(3187)* | Mean | | 8.4 |
| | | | SD | | 1.2 |
| | | | Range | | 6 – 12 |
| | | | *Missing* | | *1127* |

Of the 50 CAFES schools, 44 provided fruit and vegetable (FV) serving and consumption outcome data via lunch tray photography (2,506 students).[29] Schools were eliminated from total CAFES, four CAFES scales, and CAFES subscale development, as well as predictive validity analysis, when more than 50% of CAFES items were missing. Students who brought lunches from home (519 meals, 216 students) were also eliminated from predictive validity analysis, as well as 82 students with mislabeled lunch tray photograph files. After elimination, two predictive validity subsamples remained: the total CAFES instrument score could be calculated from 29 schools (1544 students) that supplied at least 50% of the total CAFES items; only 16 schools (1069 students) supplied at least 50% of each of the four room, table, plate, and food scale and subscale items. These two subsets of 29 and 16 schools (out of 50 total schools) were used in predictive validity analysis. Socio-demographic data for the two predictive validity samples are displayed in Table 4.1b. This study was deemed exempt by Cornell University Institutional Review Board.

[29] Fruit and vegetable consumption data were averaged from lunches on three separate days. Students who brought lunches from home were excluded from this study.

***Table 4.1b. Predictive validity subsamples: School and student level socio-demographics***

| | | **CAFES TOTAL + outcome data**[a] | | | | **4 CAFES scales + outcome data**[b] | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | ***Data Level*** | **n** *(tot)* | **Variable Levels** | **Total** # | **Total** % | **n** *(tot)* | **Levels** | **Total** # | **Total** % |
| **Location** | *School* | 29 | Arkansas | 6 | 21 | 16 | Arkansas | 2 | 12 |
| | | | Iowa | 6 | 21 | | Iowa | 4 | 25 |
| | | | New York | 13 | 45 | | New York | 7 | 44 |
| | | | Washington | 4 | 13 | | Washington | 3 | 19 |
| **Urbanity** | *School* | 29 | Urban | 9 | 31 | 16 | Urban | 6 | 38 |
| | | | Rural | 15 | 52 | | Rural | 5 | 31 |
| | | | Suburban | 5 | 17 | | Suburban | 5 | 31 |
| **Gender** | *Student* | 856 *(1544)* | Male | *403* | 26 | 595 *(1069)* | Male | 294 | 28 |
| | | | Female | *453* | 29 | | Female | 301 | 28 |
| | | | *Missing* | *688* | *45* | | *Missing* | *474* | 44 |
| **Free & reduced price meal recipients** | *Student* | 848 *(1544)* | Full | 201 | 13 | 606 *(1069)* | Full | 139 | 13 |
| | | | Reduced | 95 | 6 | | Reduced | 63 | 6 |
| | | | Free | 552 | 36 | | Free | 404 | 38 |
| | | | *Missing* | *696* | *45* | | *Missing* | *463* | *43* |
| **Grade** | *Student* | 1544 | 2nd | 724 | 47 | 1069 | 2nd | 520 | 49 |
| | | | 4th/5th | 820 | 53 | | 4th/5th | 549 | 51 |
| **Ethnicity** | *Student* | 857 *(1544)* | White | 365 | 24 | 612 *(1069)* | White | 223 | 21 |
| | | | Black | 201 | 13 | | Black | 136 | 13 |
| | | | Hispanic | 172 | 11 | | Hispanic | 153 | 14 |
| | | | Asian | 26 | 2 | | Asian | 20 | 2 |
| | | | Native American | 13 | 1 | | Native American | 12 | 1 |
| | | | Other | 80 | 5 | | Other | 68 | 6 |
| | | | *Missing* | *687* | 44 | | *Missing* | *457* | 43 |
| **Student population** *(# students)* | *School* | 29 | Mean | 419 | | 16 | Mean | 440 | |
| | | | SD | 182 | | | SD | 169 | |
| | | | Range | 120 – 894 | | | Range | 166 – 894 | |
| **% Free & reduced price meal recipients** | *School* | 29 | Mean | 68% | | 16 | Mean | 65% | |
| | | | SD | 19% | | | SD | 16% | |
| | | | Range | 43 – 100% | | | Range | 43 – 99% | |
| **Ethnicity** *(% minority students)* | *School* | 29 | Mean | 54% | | 16 | Mean | 61% | |
| | | | SD | 33% | | | SD | 27% | |
| | | | Range | 1 – 99% | | | Range | 8 – 98% | |
| **BMI** | *Student* | 373 *(1544)* | Mean | 19.7 | | 254 *(1069)* | Mean | 19.6 | |
| | | | SD | 5.4 | | | SD | 5.4 | |
| | | | Range | 11.4 – 46.4 | | | Range | 11.4 – 46.4 | |
| | | | *Missing* | *1171* | | | *Missing* | *815* | |
| **Age** | *Student* | 851 *(1544)* | Mean | 8.4 | | 590 *(1069)* | Mean | 8.4 | |
| | | | SD | 1.2 | | | SD | 1.2 | |
| | | | Range | 6 – 12 | | | Range | 6 – 12 | |
| | | | *Missing* | *693* | | | *Missing* | *479* | |

*a= Schools that provided FV lunch tray outcome data and at least 50% of total CAFES items*
*b= Schools that provided FV lunch tray outcome data and at least 50% of all four CAFES scale items*

### ***Constructs and Measures***

*Student level data*. Student gender, grade level, FRPM eligibility, ethnicity, age, and body mass index (BMI) were reported by parents in a survey distributed by Cooperative Extension Educators as part of the USDA-funded study. To obtain FV outcome data, rulers with identification numbers were attached to each student's lunch tray by Cooperative Extension Educators, then photographed twice: once after students were served and before eating, and again after eating and leaving trays with waste behind (Swanson, 2008). Digital Food Image Analysis (DFIA) software procedures quantified FV served and consumed (*see* Echon, 2012). Using school menus, cafeteria production records, and the USDA's nutrient database (sr24), DFIA software analyzed "before and after" lunch tray photograph pairs (Figure 4.2), and recorded amounts (grams) of FV served and consumed.


***Figure 4.2**. Example "pre" (left) and "post" (right) lunch tray photography images*

Objective photography procedures were used because self-report measures of children's dietary intake are unreliable (McPherson, Hoelscher, Alexander, Scanlon, & Serdula, 2000;

Rockett & Colditz, 1997; Warren et al., 2003). Photography analysis provided data on both the *total amount* of and *side dish* FV served and consumed. For example, data for a meal of lasagna containing tomato sauce with a side salad included the tomato sauce and salad in the total amount of vegetables served and consumed, but only the salad in the vegetable side item data. Of the FV served, the percentage consumed was also calculated by dividing the amount consumed by the amount served.[30] It is important to distinguish between foods available to students, what students choose to serve or are served, and what students consume because different factors affect servings and consumption (Georgiou, Martin, & Long, 2005). Reliability and validity testing of the recently developed DFIA software is in progress by USDA-funded researchers at the Social and Health Research Center in San Antonio, Texas (Echon, 2012,[31] personal communication, December, 2012).

*School level data*. Student population, percentage of students eligible for FRPM, percentage of minority students, and whether a school was urban, rural, or suburban were obtained by the research team as part of the larger USDA-funded study. CAFES items at the school level were collected via interviews with the Principal and Food Service staff, observations, and ratings from sketches and photographs. Example photographs of a cafeteria and combined kitchen and serving area are displayed in Figure 4.3.

***Figure 4.3**. Examples of a school cafeteria (left) and another school's kitchen/serving area (right)*

[30] Only foods, not beverages, consumed during lunch were used in predictive validity analysis.
[31] DFIA technology developer, Project Engineer, Lead Programmer, and Statistician: Social & Health Research Center, San Antonio, TX (www.sahrc.org).

***Procedures***

*1. CAFES item selection*. A large initial number of items were included in the preliminary CAFES version to represent the broad range of environmental attributes potentially relevant to diet within room, table, plate, and food scales. Items were selected from a variety of sources (see *Introduction*), including previous studies and USDA reports, school cafeteria observations, and existing environmental assessment instruments and resources[32] (Demment, 2012; Evans, Wells, Hoi-Yan, & Saltzman, 2000; Pikora et al., 2002; Wansink, Smith, et al., 2010). Table 4.2 displays themes drawn from these sources that guided preliminary CAFES item selection.

***Table 4.2. School cafeteria assessment items*** *(adapted from Sobal & Wansink, 2007)*

| Theme | Assessment tool item examples | Scale |
|---|---|---|
| *Availability* | Available food preparation and storage<br>Availability & variety of fruits and vegetables<br>Competitive food, beverage, and vending availability<br>Packaging/portion sizes of food items | Room<br>Table<br>Table<br>Food |
| *Accessibility: layout, display, visibility, and convenience* | Floor plan layout/circulation<br>Food and beverage arrangement and display<br>Lunch tray availability<br>Food preparation (e.g., whole or sliced fresh fruit) | Room<br>Table<br>Plate<br>Food |
| *Naming and labeling* | Creativity of food item naming on menus<br>Labeling of individual food items | Table<br>Table |
| *Advertising and signage* | Healthy eating promotion<br>Commercial soft drink advertising | Room<br>Room |
| *Ambient environment* | Temperature<br>Crowding and noise<br>Odor<br>Lighting<br>Presence of windows<br>Appearance/structural condition and quality<br>Clutter and cleanliness<br>Seating and furniture<br>Food presentation/attractiveness | Room<br>Room<br>Room<br>Room<br>Room<br>Room<br>Table<br>Table<br>Table |

*Pilot testing*. An initial version of CAFES that included all possible items was pilot-tested at a local elementary school. Three trained researchers used the preliminary protocol to complete observational checklists, rating scales, draw a floor plan and food layout plan, and photograph the cafeteria, serving, and kitchen areas. School staff, when available, were consulted as uncertainties arose (e.g., food layout when no food was present, number

[32] CAFES built upon a preliminary school environment checklist developed through a Robert Wood Johnson Foundation, Active Living Research dissertation grant (Demment, 2012).

of students who ate during a meal period). Based on pilot data, which required approximately 45 minutes to collect at each school, item order was adjusted and instructions were clarified. Because Cooperative Extension Educators had limited time available and collected data without training, a “short version” of CAFES items was developed. Additional items were then documented by trained researchers from Extension Educator photographs when possible.[33]

*Data collection*. Trained researchers and Cooperative Extension Educators completed observations, rating scales, floor plan and food layout sketches, and photographed the cafeteria, kitchen, and food serving areas. Other items[34] were obtained from Cooperative Extension Educator surveys, interviews with school principals and food service staff, and lunch tray photography as part of the larger USDA funded study.

*Photograph, floor plan, and food layout coding*. Because observation time at each school was limited, photographs and sketches were used by researchers to later complete any missing items or CAFES items omitted from the short form that was used by Cooperative Extension Educators.[35] Researchers and Cooperative Extension Educators were rarely able to observe students during meal time, therefore, recording CAFES items at the plate and food scales was challenging. Photographs of students’ meals on lunch trays

[33] Items not included in the short version or gathered from photographs: cafeteria square footage, cafeteria temperature, air conditioning availability, and music availability. Any item that could not clearly be established from photographs due to photo quality was considered missing data.

[34] Other item examples: students per meal time (obtained on site when staff present); whether lack of display, preparation, or storage space limited offering healthy options; whether suitable equipment and adequate storage space aided in offering healthy options; whether school meals were cooked at or just reheated on site (obtained on site when staff present); weekly availability of baked goods, fries, ice cream, pasta, pizza, salad, whole grains, and milk; whether fundraisers with food during lunch and/or in the cafeteria were allowed; whether a la carte lunch options and portion sizes that differed by age were offered; whether vending machines were available for student use (obtained on site when staff present); whether students served themselves for salads or a la carte entrees/sides; weekly availability of more than one main course, fruit, and vegetable; weekly frequency of reheating meals (vs. freshly prepared).

[35] *Image coding items*: Rate cafeteria, serving, and kitchen space, furniture, and lighting; menu location; student circulation (clear path from entrance to food, seating, trash, and exit); cafeteria obstructions (e.g., columns) that could inhibit circulation; FV presentation; serving area food presentation attractiveness; tray rest presence; kitchen and serving area clutter/cleanliness; milk availability/layout; food layout/placement; serving tray color, material, and compartment quantity.

before consumption were therefore used to code plate and food scale items.[36] For each school, one photo of each meal entrée and variation (e.g., different side items) was coded for each of the three days that lunch tray data collection occurred.[37] Four undergraduate research assistants were first trained using sample school cafeteria, serving area, and kitchen images and then coded all photographs and sketches. Inter-rater reliability of the coding results, after correcting data entry errors (e.g., changing "0.50" to "50%" and correcting obvious typos), is displayed in Table 4.3. All coding results were carefully reviewed to resolve any coding or data entry errors, omissions, and discrepancies. The average rating for subjective categorical variables (e.g., attractiveness) and the mode of objective variables (e.g., number of fruits on a lunch tray; is the lunch tray plastic or not) were then used in analyses to select final CAFES items.

***Table 4.3. Inter-rater reliability and percent agreement for image coding***

| Data type & location | No. Coded Items | No. Schools | No. Instances | Item type | Reliability statistic | |
|---|---|---|---|---|---|---|
| ***Continuous Variables*** | | | | | | |
| Serving Area | 7 | 33 | 109 | Objective | Ebel= | 95.0% |
| ***Categorical variables*** | | | | | | |
| TOTAL | 95 | 35 | 1678 | Objective & subjective | Percent agreement (consensus)= | 71.8% |
| Cafeteria | 71 | 34 | 1051 | | | 71.4% |
| Serving Area | 16 | 35 | 404 | | | 71.9% |
| Kitchen | 8 | 34 | 223 | | | 73.5% |

Inter-rater reliability was high for the continuous, objective serving area variables (Ebel = 95.0%). Because the categorical variables included both objective and subjective items, agreement was lower, but at 70%, was still at an acceptable level.

[36] *Lunch tray photograph items*: meal presentation, # fried items, # fruits, # vegetables, # raw fruits and vegetables, # of packaged reheated items, total # food items; # tray colors and types, # tray compartments, tray material (plastic or styrofoam), tray area.

[37] Plate scale items were coded based on one to ten photos per school (27 schools, 63 photos) and varied based on the total number of tray types (shape, size) and colors available to students. The number of photos used to code food scale items ranged from one to eight per school (27 schools, 128 total photos) and varied based on the number of available meal options, variations, and days (1-3) of data collection.

*2.* *<u>Scale development and internal consistency (reliability)</u>.* All CAFES items were entered into IBM SPSS Statistics for Windows (IBM Corp., Version 21.0) and dichotomously recoded into negative (0) and positive (1) scores, then grouped based on scale (see CAFES instrument and codebook, Appendices F and G). Due to variations in school environments, available staff, photo quality, and time constraints, not all items were obtained from each school, which resulted in missing data. Therefore, during CAFES development, only schools with less than 50% missing data within each scale or subscale were included in analysis. Sample sizes did not support imputation of missing values.

The relatively small school sample size and large number of CAFES items prevented the use of factor analysis or item-scaling. Instead, variability of each item and inter-item correlations of all CAFES items, items within each of the four scales, and subscale items were calculated and served as criteria for item omission. Items with both the lowest variability and inter-item correlations were omitted from the overall CAFES measure, four scales, and subscales. Kuder-Richardson 21 (KR-21)[38] coefficients were used as a measure of internal consistency of CAFES total and four scale scores. Variable omission procedures were repeated until KR-21 coefficients of the total CAFES instrument, four scales, and room and table subscales reached 0.70 when possible. No plate or food scale subscales emerged as reliable with data from this study sample.

CAFES total, four scale, and subscale scores were calculated by summing all items. Since some CAFES items were missing from each school, summed scores were divided by the total number of completed items to yield a percentage score out of 100%. Scores indicated how well the cafeteria environment promoted or inhibited healthy serving and consumption within the four cafeteria scales and subscales.

[38] KR-21 coefficients assess internal consistency of binary items (scored as 0 and 1). KR-21 assumes, although unrealistically, that all items in the scale have equal difficulty levels (Cortina, 1993). For CAFES research purposes, a minimum reliability of 0.70 was desired, indicating 70% consistency in CAFES scores and subscale scores. Although higher consistency may be desired (e.g., 0.90 for achievement tests), 0.70 was selected as appropriate for CAFES (Cortina, 1993).

*3. Face validity*. During the item-selection process, face validity was evaluated based on feedback from experts at Cornell University and members of the USDA-funded study who were asked to review items for representativeness and relevance.

*Predictive validity* was assessed using Hierarchical Linear Modeling software (Version 7.0; Raudenbush, Bryk, & Congdon, 2011) to determine whether CAFES total (A), four scale (B), and subscale (C) scores significantly predicted FV serving and consumption outcomes among elementary school students. The hierarchical, two-level data structure consisted of student level controls (grade, gender, BMI) nested within school level CAFES scores (CAFES total, four scale, and subscale scores) and school level controls (percent of students receiving free and reduced price meals, percent minority student population, urbanity). The sample size was not large enough to explore a three-level model (students within classes within schools). All variables except CAFES scores were grand-mean centered.

Three sets of multilevel models were run using the following sets of school level predictors: 1) total CAFES score, 2) room, table, plate, and food scale scores, and 3) individual room, table, plate, and food scale scores; individual room scale subscale scores; and individual table scale subscale scores. Six FV outcome variables included: total FV served, total FV consumed, side dish FV served, side dish FV consumed, percentage consumed of total FV served (total FV percentage consumed), and percentage consumed of side FV served (side FV percentage consumed). Sample sizes for the percentage consumed outcomes were smaller than all other outcome variables because only students who were served or served themselves more than zero grams of FV were included. CAFES development and scores, CAFES reliability results, and CAFES predictive validity analyses are presented in the following *Results* section.

## RESULTS

### *1. CAFES items and subscales*

Brief descriptions of the final 198 CAFES items, organized by scale and subscale, are displayed in Table 4.4. Objective observer ratings were used whenever possible, but 105 items concerning food and beverage availability were obtained from school staff interviews. A complete list of CAFES items, descriptions, and coding is included in the final CAFES instrument version (Appendix F) and codebook (Appendix G). Only lunch items were included in CAFES, although some schools participated in breakfast, snack, weekend, and farm-to-school programs. Food item portion sizes, regulated by federal school meal programs across all participating schools, were also excluded from CAFES. Two Iowa schools did not provide at least 50% complete data for any final CAFES scale or subscale and were therefore excluded from scale development and analysis. The following sections describe each scale, subscale, and item, as well as omitted items. For this sample, 149 CAFES items (of the 198 possible CAFES items) were selected for analysis based on sample size, variability, and reliability.

**Table 4.4. CAFES scales, subscales, and example items**

**ROOM SCALE** (46 / 54)

| **Cafeteria Ambient Environment** (7/9) | **Cafeteria & Serving Area Appearance** (8/9) | **Cafeteria Fenestration** (8/8) | **Layout & Visibility** (8/8) | **Advertising** (1/6) | **Kitchen & Serving Area Environments** (14/14) |
|---|---|---|---|---|---|
| Temperature (2), music, odor, crowding (2), ceiling height, *lighting, noise* | Cafeteria attractiveness, physical condition, furniture condition, clutter, cleanliness; serving area attractiveness, physical condition, clutter, *cleanliness* | Are there windows; window condition, quantity, view, operability, transparency, screens, and/or treatments | Student circulation, plan obstructions, menu location, lack of display space, lack of prep area, food/beverage visibility from cafeteria, vending machine visibility from cafeteria | Presence of healthy and unhealthy diet/physical activity signage (2); *quantity (2), location (2)* | Is lunch cooked at school or elsewhere; serving area equipment condition, lighting; kitchen presence, attractiveness, cleanliness, clutter, lighting, physical condition, equipment condition and availability, window presence, storage space availability (2) |

**TABLE SCALE** (95 / 129)

| **Cafeteria Furniture** (4/4) | **Availability** (56/77) | **Display Layout & Presentation** (8/10) | **Serving Method** (11/19) | **Variety** (16/19) |
|---|---|---|---|---|
| Furniture attractiveness, table shape; seating (bench or individual seats; attached or moveable) | Weekly availability*: food (45/55), a la carte (1/6), beverage items (5/10); fundraisers (2), vending availability (2); age appropriate portion sizes; *ice cream cooler availability* | Fruit presentation, FV close to register, FV in first 3 visible items, milk layout, menu item naming, food item labeling, serving area food attractiveness, milk location, *ice cream lid transparency, out of reach/by request only items* | Tray rest available, serving tray use, self-serve option & for which items* (3/4); large trays or premeasured portions (3), packaging transparency (3); *sharing table availability, seconds allowed (2), offer vs. serve (4)* | Weekly availability*: more than one main course (3/6), fruit (6), vegetable (6) offered; milk quantities offered |

**PLATE SCALE** (3 / 4)

| | |
|---|---|
| Lunch tray area, color, material (styrofoam or not) | *Utensils* |

**FOOD SCALE** (5 / 11)

| | |
|---|---|
| Reheat frequency* (1/6), avg # fruits per meal, avg # vegetables per meal, # meals w/ fried item; % FV that are raw | *Fresh fruit whole or sliced* |

***(# / #)*** = *number of items used in current CAFES study / number of items included in FINAL CAFES version*
***Italicized text*** = *item excluded from the current CAFES study, but included in final CAFES instrument*
* = *Items added to final CAFES version to include individual item for each day of the week, including zero (refer to Results section)*

_Room scale_ (46/54 items[39]). The room scale captured attributes of the cafeteria and serving areas that students directly encounter during lunch. Items within this scale were categorized by six subscales: cafeteria ambient environment, cafeteria and serving area appearance, cafeteria fenestration, layout and visibility (access), advertising, and kitchen and serving area environments. Items within storage environments such as shelves, pantries, and cabinets (Sobal & Wansink, 2007) were not included in CAFES analysis.

-*Cafeteria Ambient Environment* (7/9 items). Ambient environmental conditions included temperature (too hot/cold or comfortable; air conditioning available or not), music availability (yes/no), odor (unpleasant or none/pleasant), crowding which also served as a proxy for noise (students per table; above or below square footage standards based on number of students and table type[40]), and ceiling height (above or below design standards[41]). Cafeteria lighting was omitted from this analysis due to poor quality photographs, but was still included in the final CAFES instrument. Since observations were not permitted during lunch, a direct observation or measure of noise could not be included, but items to rate lighting and noise were included in the final CAFES instrument. Variables relating to windows were consistent as a separate fenestration subscale.

-*Cafeteria & Serving Area Appearance* (8/9 items). Cafeteria and serving area attractiveness were rated based on overall condition, brightness, and cleanliness. Other items included cafeteria physical condition, furniture condition, clutter, and cleanliness; and serving area physical condition and clutter. Items were rated as great (1), good (1), fair (0), or poor (0). Serving area cleanliness was excluded from this sample, and cafeteria design characteristics such as color, material, and decoration were not included in CAFES items.

[39] Refer to (#/#) note below Table 4.4 for explanation of these two numbers.
[40] Design standards for elementary school cafeterias: Rectangular tables with attached seats: 8-10 square feet (SF) per student; Rectangular tables with stackable chairs: 10-11 SF/student; Round tables with attached seats: 11-14 SF/student; Round tables with stackable chairs: 14-15 SF/student (Office of Support Services, VA Department of Education, 2010).
[41] Cafeterias measuring less than 3000SF in area should have ceiling heights that are at least 12' tall; cafeterias above 3000SF should have a ceiling height of at least 14' (Office of Support Services, VA Department of Education, 2010).

-*Cafeteria Fenestration* (8/8 items). Physical window condition was also rated as great, good, fair, or poor. Other subscale items included whether or not windows were present, window quantity (percentage of total wall area), the amount of nature present through window views, and whether windows were operable, transparent, had screens, or had treatments (blinds, curtains, or shades).

-*Layout & Visibility* (8/8 items). This subscale included eight items related to the arrangement of spaces that directly and indirectly affected student circulation, actual and perceived access, visibility, and convenience of food and beverage item access. The student circulation path item examined whether or not students were able to easily move between or access the entry, menu, tray pickup, food and beverage, payment, seating, trash, and exit without overlapping, backtracking, or skipping any food stations. Poor circulation affected the convenience of accessing different foods. For example, in one cafeteria, students entered the serving area in one line, but then split into two lines in opposite directions, each with different food, to obtain and pay for their meal. The salad bar was on one side of the line so students had to make their way through both lines to obtain foods from each location if desired. Plan obstructions similarly noted whether columns or other obstructions existed in the cafeteria and serving area that affected circulation, views of, or access to food and beverage items. Menu location indicated whether the menu was positioned where students could see it before obtaining meal items, which were often not labeled. Lack of display space and lack of preparation area were reported by food service staff and indicated whether those challenges limited offering more healthy options to students. Visibility of food and beverage items and vending machine visibility captured whether students had a view of healthy or unhealthy options while eating.

-*Advertising* (1/6 items). Complete data was only gathered for one advertising and signage subscale item and was defined by the presence or absence of signage in school cafeterias and serving areas pertaining to healthy or unhealthy diet (eat five fruits and vegetables (FV) per day vs. soft drink advertisement) and physical activity (exercise more vs. television advertisement). Not enough information was collected from this sample concerning signage quantity or location (on food displays, walls, at eye level, along the serving line or not etc.) to further develop the subscale. Although a single item is not reliable in measuring a construct and should not be used to make inferences, the presence or absence of healthy and unhealthy eating and physical activity signage was not internally consistent with any other subscale construct and was thus kept as a separate variable. The final CAFES instrument contains six items concerning healthy and unhealthy content, quantity, and location.

*-Kitchen & Serving Area* (14/14 items). Because students only encountered kitchen and serving areas, often separate from eating areas, when obtaining food and beverage items, a separate subscale for the kitchen and serving area environment was developed.[42] Fourteen items included whether lunches were cooked at the school or elsewhere, whether the school had a kitchen, physical kitchen and serving area conditions, equipment condition and availability, storage space availability, lighting, windows, attractiveness, cleanliness, and clutter. Serving area cleanliness, serving area and kitchen square footage, and design characteristics of both spaces were excluded from CAFES. Serving area cleanliness[43] was omitted because of inconsistent and missing data. All areas were clean at the beginning of a meal and when no meals were being prepared, but ratings widely varied just after or during meal times.

*Table scale* (95/129 items). Items within the table scale, relating to surfaces from which foods and beverages are served and consumed, were separated into five subscales: furniture, availability, display layout and presentation, serving method, and variety. Kitchen and serving equipment inventory were excluded beyond food service staff responses to how storage space, equipment, display space, and preparation space helped or hindered offering

[42] An original CAFES item included whether serving and kitchen areas were integrated or separate spaces, but this variable was eliminated during reliability analysis.
[43] Serving area cleanliness, especially of serving vessels and surfaces, during a meal were more reflective of serving method, e.g., whether students were allowed to serve themselves.

healthy items. Because foods were most often absent from serving areas during observation, additional items excluded from the table scale were: order of serving, fullness (emptiness/saturation) of food and beverage serving sources, spot lighting on individual food items, serving vessel size, and serving surface color and material (Sobal & Wansink, 2007).

-*Cafeteria Furniture* (4/4 items). This subscale consisted of four items gathered during observation: furniture attractiveness (great, good, fair, poor), table shape (circular or not), chair type (benches or individual seats), and chair attachment (attached or moveable). Furniture condition was internally consistent with the overall cafeteria appearance subscale at the room scale level. Color, style, and furniture layout were not included in this subscale.

-*Availability* (56/77 items). Food service staff reported the average weekly availability (0, 1, 2, 3-4,[44] or 5 days/week) of: whole grains, fruits, vegetables, pasta, French-fried potatoes, pizza, low- and non-low fat baked goods, and low- and non-low fat ice cream. Five variables were created for each food item to account for schools that offered various options, such as salad, five days per week versus two days per week. Six items were included in the final CAFES version to capture availability for each week day (0-5), including a la carte lunch meals. Other items included whether or not age appropriate portion sizes and a la carte lunch meals were offered; the availability of low, reduced, full, flavored, and unflavored milk options; vending machine availability; and lunch time fundraisers. The presence of an ice cream cooler was excluded from this analysis due to missing data and low variability.

-*Display Layout & Presentation* (8/10 items). This subscale covered food and beverage item display layout and presentation, which affects actual and perceived access and visibility within table scale. Items included the attractiveness of serving area foods and beverages, the presentation (decorative bowl or metal/plastic tray) and placement (near the register or not) of fresh fruit, the placement of FV (within the first three visible items), how

[44] The final CAFES version included separate items for three and four days per week.

items are named on the menu (by item, descriptively, or creatively), and whether individual food and beverage items are labeled or not. The transparency of ice cream cooler lids was excluded since ice cream cooler availability was omitted from the table scale availability subscale due to low variability. Whether or not any items were kept out of students' reach (e.g., behind counters) and available by request only was also excluded because it could not be reliably coded without food present during observations and in photographs.

-*Serving method* (11/19 items). The serving method subscale included two items that noted the availability of serving trays and tray rests to students, which also captured perceived access and convenience. Students, especially younger children, struggle to simultaneously carry plates, bowls, beverages, and utensils, or balance trays and serve themselves food without a place to set down their tray. Without trays or tray rests, self-serve fruit and salad bars are especially challenging (NY school food service employee, personal communication, January, 2012; Wansink, Just, & Shimizu, 2011). Other items included whether salads and a la carte entrees and sides were self-serve or not; whether desserts, snacks, fruits, and vegetables were served in individual portions from larger vessels (trays, bowls, pots etc.); and whether any packaging of these items was transparent or not. One item excluded from this subscale but included in the final CAFES instrument was the presence of a "sharing table." A few schools identified a location where leftover fruits, vegetables, milk, and other lunch items could be placed for other students to take free of charge. This affected fifth graders' consumption of FV, especially when their portion sizes were too small and they often complained of being hungry (NY food service employee 2, personal communication, January, 2012). A second excluded item was whether fresh fruits were served whole or sliced. Because food was often not present during all school observations, observers could not reliably record this variable. The variable could also not be reliably coded from lunch tray photographs.

-*Variety* (16/19 items). The final table scale subscale included the number of days per week (1-5) more than one main course, fruit, and vegetable option was available to students (reported by food service staff). This indicated whether or not students had choices to make among these items, and how often. Similar to the availability subscale, six indicator variables (for 0-5 week days) were included in the final CAFES version for each item to account for schools that offered choices five verses two days per week. The proportion of different types of milk available each day was also recorded (observations and photographs). When looking at the milk cooler from which students are served or serve themselves, the total number of milk crates visible to students was counted. Then, the number of crates of each milk type was divided by the total number (0=<50% white milk, 1=≥50% white milk).

*Plate scale* (3/4 items). Three of the four final plate scale items were internally consistent: lunch tray area (size), lunch tray color (whether there was more than one color choice), and lunch tray material (styrofoam or plastic). Eating utensils were excluded from this analysis, but an item was added to the final CAFES instrument after data collection. This addition was made because one school district was only allowed to provide plastic "sporks" (combined fork and spoon) to their students and no knives. This made it difficult for students to cut meat and whole fruits such as kiwi, affecting their ability to eat certain items (NY Cooperative Extension Educator, personal communication, January, 2012). Serving utensils and milk carton packaging were also excluded from CAFES, as well as items related to package labeling and containers (boxes, cans, bottles; Sobal & Wansink, 2007).

*Food scale* (5/11 items). Five of the 11 food scale items coded from lunch tray photographs were internally consistent: meal freshness (frequency meals reheated at school: 0=3-5 times/week; 1=1 or 2 times/week); number of fruits (0=0, 1=≥1), vegetables (0=0, 1=≥1), and fried items (0=≥1, 1=0) on a lunch tray; and the number of raw FV on a tray (0=<50% FV, 1=≥50% FV). The final CAFES version includes six (vs. 1) meal freshness items to capture frequency (0-5 days per week), instead of just whether or not foods were reheated. Whether fresh fruits were served whole or sliced was not assessed; however, this item was added to the final CAFES instrument. Items excluded from the food scale were meal temperature, taste, texture, and attractiveness because students were not interviewed. Divisions or demarcations on food surfaces, patterns, and color (Sobal & Wansink, 2007) were also excluded from CAFES.

***2. CAFES reliability***

The reliability of CAFES was assessed in three ways: inter-rater reliability of photo coding; internal consistency (KR-21) for the total CAFES, four scale, and two subscale scores; and mean inter-item correlations among items in the overall CAFES measure, four scale, and two subscales. First, inter-rater reliability for all photo-coded items was calculated as reported in the Methods section (Ebel=95% for continuous items; percent agreement ranged from 71.3 – 74.5% for categorical items). Inter-rater reliability of the entire CAFES measure was not assessed due to limited time available for school observations to be conducted repeatedly and limited Cooperative Extension Educator resources. Reliability coefficients and inter-item correlation matrices were also used to assess CAFES reliability. CAFES total, scale, and subscale scores, descriptives, reliability coefficients, and mean inter-item correlations are displayed in Table 4.5.

**Table 4.5. CAFES scores and analysis**

| CAFES score *(Subscale)* | n[a] | # items | CAFES Score | | | CAFES Score Analysis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean[b] | SD | Range | Skewness[c] | SE | Kurtosis[d] | SE | KR-21 | Mean r[e] |
| **TOTAL SCORE** | **36** | **149** | **50.54%** | **5.96%** | **34.57% - 64.34%** | **-0.172** | **0.393** | **.575** | **0.768** | **0.88** | **0.18** |
| **Room scale** | **38** | **46** | **70.10%** | **10.13%** | **43.90% - 87.50%** | **-0.296** | **0.383** | **-0.384** | **0.750** | **0.80** | **0.18** |
| *Ambient* | *28* | *7* | *61.84%* | *19.82%* | *28.57% - 100.00%* | *-0.082* | *0.441* | *-0.414* | *0.858* | *0.75* | *0.22* |
| *Appearance* | *37* | *8* | *75.98%* | *23.36%* | *12.50% - 100.00%* | *-0.908* | *0.388** | *0.153* | *0.759* | *0.71* | *0.23* |
| *Fenestration* | *35* | *8* | *53.48%* | *31.71%* | *0.00% - 100.00%* | *-0.408* | *0.398* | *-1.171* | *0.778* | *0.81* | *0.44* |
| *Layout* | *37* | *8* | *91.29%* | *16.98%* | *37.50% - 100.00%* | *-2.190* | *0.388** | *4.208* | *0.759** | *0.83* | *0.34* |
| *Ads* | *37* | *1* | *86.47%* | *34.66%* | *0.00% - 100.00%* | *-2.226* | *0.388** | *3.120* | *0.759** | *n/a* | *n/a* |
| *Kitchen/Serve* | *40* | *14* | *63.71%* | *14.67%* | *25.00% - 85.71%* | *-0.563* | *0.374* | *0.274* | *0.733* | *0.71* | *0.16* |
| **Table scale** | **36** | **95** | **42.64%** | **6.78%** | **29.58% - 62.29%** | **1.014** | **0.393*** | **1.668** | **0.768*** | **0.72** | **0.19** |
| *Furniture* | *36* | *4* | *33.10%* | *25.70%* | *0.00% - 75.00%* | *0.207* | *0.393* | *-1.079* | *0.768* | *0.52* | *0.20* |
| *Availability* | *36* | *56* | *40.48%* | *8.17%* | *25.93% - 62.50%* | *0.491* | *0.393* | *0.236* | *0.768* | *0.71* | *0.17* |
| *Display* | *35* | *8* | *39.90%* | *22.95%* | *0.00% - 85.71%* | *0.106* | *0.398* | *-0.794* | *0.778* | *0.80* | *0.23* |
| *Serving method* | *34* | *11* | *64.90%* | *13.47%* | *36.36% - 90.91%* | *0.023* | *0.403* | *-0.564* | *0.788* | *0.64* | *0.24* |
| *Variety* | *36* | *16* | *40.09%* | *20.42%* | *18.75% - 93.33%* | *0.601* | *0.393* | *-0.522* | *0.768* | *0.82* | *0.40* |
| **Plate scale** | **37** | **3** | **51.35%** | **44.16%** | **0.00% - 100.00%** | **-0.054** | **0.388** | **-1.804** | **0.759*** | **0.83** | **0.66** |
| **Food scale** | **27** | **5** | **51.73%** | **20.94%** | **20.00% - 100.00%** | **0.082** | **0.448** | **-0.441** | **0.872** | **0.58** | **0.24** |

*[a]= Sample sizes indicate schools with at least 50% CAFES items at this scale/subscale collected*
*[b]= CAFES scores are all out of a maximum of 100%. Each school's total was divided by the total # of completed CAFES items*
*[c]= Skewness is a measure of symmetry of the data distribution. A * in the SE column indicates skewed data (based on a Skewness value that does not fall between -SE x 2 and +SE x 2)*
*[d]= Kurtosis is a measure of how peaked (+) or flat (-) the data distribution is relative to a normal distribution. A * in the SE column indicates a non-normal distribution (based on a Kurtosis value that does not fall between –SE x 2 and +SE x 2)*
*[e]= Mean inter-item correlation*

CAFES scores indicated how well the cafeteria environment promoted or inhibited healthy serving and consumption outcomes within the four cafeteria scales and subscales. The mean total CAFES score for all schools was 51% out of a maximum 100%. Average room scale score was the highest scale score (70%), followed by the food scale (52%), plate scale (51%), and table scale (43%). Schools scored well within the appearance and layout room scale subscales, averaging 76% and 91%, respectively. Other room scale subscales averaged 54% (fenestration), 62% (ambient), and 64% (kitchen and serving area). With the exception of the table scale serving method subscale (65%), average table scale subscale scores were low at 33% (furniture), 41% (availability), 40% (display), and 40% (variety).

Analysis of the total, scale, and subscale scores revealed that data within room scale appearance and layout subscales were negatively skewed,[45] but positively skewed within the table scale (see skewness and kurtosis columns, Table 4.5). Scores within the room scale appearance and layout subscales, and table scale, were peaked (leptokurtic) relative to a normal distribution, and plate scale data were flat (platykurtic) relative to a normal distribution.

The second measure of internal consistency, the Kuder-Richardson 21 reliability coefficient (see footnote 38 and KR-21 column in Table 4.5) indicated fairly strong reliability for the overall CAFES score (KR-21= 0.88). The KR-21 reliability coefficient for the total CAFES measure, and the room, table, and plate scales exceeded 0.70, but the food scale did not (0.58). The advertising and signage (room scale), furniture (table scale), and serving method (table scale) subscales also did not meet the 0.70 criterion. Third, mean inter-item correlations within all scales and subscales were calculated, but were low except for plate scale (0.66), room scale fenestration subscale (0.44), and table scale variety subscale (0.44). Inter-item correlation matrices for the overall CAFES and scale scores, room scale

[45] Reliability analysis of the ads/signage "subscale" are not discussed since only one item was included in this analysis.

subscales, and table scale subscales were also calculated and are presented in Tables 4.6, 4.7, and 4.8, respectively.

***Table 4.6. Pearson correlations among CAFES total and scales scores***

| *Score* | | *1* | *2* | *3* | *4* | *5* |
|---|---|---|---|---|---|---|
| **1.** | **CAFES score** | -- | 0.64** | 0.83** | 0.37* | -0.33 |
| | *(n)* | | *32* | *36* | *30* | *20* |
| **2.** | **Room scale** | | -- | 0.14 | 0.13 | 0.02 |
| | *(n)* | | | *32* | *29* | *19* |
| **3.** | **Table scale** | | | -- | 0.15 | -0.47* |
| | *(n)* | | | | *30* | *20* |
| **4.** | **Plate scale** | | | | -- | -0.17 |
| | *(n)* | | | | | *26* |
| **5.** | **Food scale** | | | | | -- |
| | *(n)* | | | | | |

** = p< 0.05 level (two-tailed)* *** = p< 0.01 level (two-tailed)*

The overall CAFES score was significantly correlated with the room scale (0.64), table scale (0.83), and plate scale (0.37) scores (Table 4.6). The strong, significant correlation between the total CAFES score and room and table scale scores was expected considering that those two scales contained the largest numbers of items when compared to the plate and food scales. The low and insignificant inter-item correlations between the four scale scores, except between table scale and food scale, indicated that items within each scale were measuring separate constructs.

Within the room scale, the overall room scale score was marginally to significantly correlated with the appearance, fenestration, layout, and kitchen and serving area subscale scores (Table 4.7). Insignificant correlations between room scale subscale scores indicated that the subscales were measuring separate constructs within the room scale. The overall table scale score, however, was fairly strongly and significantly correlated with the availability subscale (0.79, Table 4.8), due to the large number of availability subscale items. The furniture and variety subscales were also marginally correlated with the overall table scale score (Table 4.8), although the furniture subscale was not internally consistent.

**Table 4.7. Pearson correlations among room scale and subscale scores**

| | SCALE/subscale | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 1. | **ROOM SCALE** | -- | 0.19 | 0.48** | 0.43* | 0.41* | -0.21 | 0.59** |
| | *(n)* | | *25* | *32* | *31* | *32* | *32* | *31* |
| 2. | **Ambient** | | -- | -0.01 | -0.05 | 0.31 | -0.50* | -0.25 |
| | *(n)* | | | *24* | *25* | *24* | *25* | *23* |
| 3. | **Appearance** | | | -- | 0.23 | -0.13 | -0.10 | 0.19 |
| | *(n)* | | | | *30* | *31* | *31* | *30* |
| 4. | **Fenestration** | | | | -- | -0.26 | 0.04 | -0.16 |
| | *(n)* | | | | | *30* | *31* | *29* |
| 5. | **Layout** | | | | | -- | -0.13 | 0.12 |
| | *(n)* | | | | | | *31* | *31* |
| 6. | *(Ads***)* | | | | | | -- | -0.19 |
| | *(n)* | | | | | | | *30* |
| 7. | **Kitchen/Serving** | | | | | | | -- |
| | *(n)* | | | | | | | |

** = p< 0.05 level (two-tailed)* *** = p< 0.01 level (two-tailed)*
**** This "subscale" only included one item*

**Table 4.8. Pearson correlations among table scale and subscale scores**

| | SCALE/subscale | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1. | **TABLE SCALE** | -- | 0.56** | 0.79** | 0.08 | 0.12 | 0.53** |
| | *(n)* | | *27* | *33* | *27* | *25* | *33* |
| 2. | **Furniture** | | -- | 0.38 | -0.09 | -0.15 | 0.29 |
| | *(n)* | | | *27* | *28* | *26* | *27* |
| 3. | **Availability** | | | -- | -0.26 | 0.02 | 0.03 |
| | *(n)* | | | | *27* | *25* | *33* |
| 4. | **Display** | | | | -- | 0.41* | -0.03 |
| | *(n)* | | | | | *26* | *27* |
| 5. | **Serving method** | | | | | -- | -0.33 |
| | *(n)* | | | | | | *25* |
| 6. | **Variety** | | | | | | -- |
| | *(n)* | | | | | | |

** = p< 0.05 level (two-tailed)* *** = p< 0.01 level (two-tailed)*

### *3. CAFES predictive validity*

Although only combined FV outcome variables were explored using multilevel modeling, a descriptive summary of these six outcome variables is presented along with summary statistics of separate fruit and vegetable outcomes for comparison in Table 4.9. Table 4.9a displays FV outcome summary statistics for the entire sample of 44 schools that collected lunch tray photography data. Table 4.9b summarizes FV outcome variables for the 29-school sample that provided at least 50% of the total CAFES items, and Table 4.9c contains FV outcome summaries for the 16 schools with at least 50% of all items in each of the four scales. FV outcome summaries are not shown for individual subscale analyses, but sample sizes ranged from 27 – 30 schools and 1441 – 1651 students. Overall, students served and consumed more fruit than vegetables. Unlike college students who have been found to consume, on average, 92% of foods they serve themselves (Wansink & Cheney, 2005; Wansink, Van Ittersum, et al., 2006), elementary school students in the overall lunch tray and predictive validity subsamples only consumed, on average, 52% - 65% of the FV served. Students in the predictive validity subsamples (29 and 16 schools) served and consumed higher amounts of total and side FV when compared to the overall sample (44 schools). Note that because students in the predictive validity subsamples served and consumed more FV than the total sample, schools with lower serving and consumption outcomes that would likely benefit most from CAFES assessment and recommended interventions were excluded from the predictive validity analysis.

*Table 4.9a. Student fruit and vegetable (FV) servings, consumption, and percent consumed*

| | N Schools | N Students | **FV served** *(grams)* | | **FV consumed** *(grams)* | | n* | **FV percentage consumed** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Mean (*SD*)** | **Range** | **Mean (SD)** | **Range** | | **Mean (SD)** | **Range** |
| ***TOTAL MEAL*** | | | | | | | | | |
| Fruits | 44 | 2506 | 102.91 *(87.73)* | 0 – 522.24 | 65.86 *(76.12)* | 0 - 514.10 | 2077 | 65% *(37%)* | 0 - 100% |
| Vegetables | 44 | 2506 | 65.98 *(73.64)* | 0 – 527.41 | 37.42 *(53.12)* | 0 – 514.10 | 2042 | 58% *(35%)* | 0 - 100% |
| **Total FV** | 44 | 2506 | 170.35 *(122.93)* | 0 - 1028.19 | 104.25 *(99.62)* | 0 - 1028.19 | 2371 | 63% *(32%)* | 0 - 100% |
| ***SIDE DISH*** | | | | | | | | | |
| Fruits | 44 | 2506 | 102.38 *(87.40)* | 0 – 522.24 | 65.74 *(75.90)* | 0 - 514.10 | 2024 | 65% *(37%)* | 0 - 100% |
| Vegetables | 44 | 2506 | 42.02 *(49.17)* | 0 - 514.10 | 23.90 *(37.31)* | 0 - 514.10 | 1799 | 57% *(38%)* | 0 - 100% |
| **Total FV** | 44 | 2506 | 145.61 *(109.95)* | 0 - 1028.19 | 90.35 *(92.57)* | 0 - 1028.19 | 2314 | 63% *(34%)* | 0 - 100% |

** = "FV percentage consumed" is reported only for students who served or were served more than 0 grams of fruits and vegetables*

**Table 4.9b. CAFES predictive validity subsample: Student FV servings, consumption, and percent consumed**

| | n Schools | n Students | FV served *(grams)* | | FV consumed *(grams)* | | n* | FV percentage consumed | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mean (*SD*) | Range | Mean (SD) | Range | | Mean (SD) | Range |
| ***TOTAL MEAL*** | | | | | | | | | |
| Fruits | 29 | 1544 | 118.38 *(92.58)* | 0 – 522.24 | 75.69 *(83.20)* | 0 - 514.10 | 1318 | 65% *(38%)* | 0 - 100% |
| Vegetables | 29 | 1544 | 63.52 *(61.99)* | 0 – 527.41 | 37.94 *(50.28)* | 0 – 514.10 | 1271 | 58% *(35%)* | 0 - 100% |
| **Total FV** | 29 | 1544 | 183.90 *(125.45)* | 0 - 1028.19 | 114.91 *(106.64)* | 0 - 1028.19 | 1478 | 63% *(32%)* | 0 - 100% |
| ***SIDE DISH*** | | | | | | | | | |
| Fruits | 29 | 1544 | 117.75 *(91.91)* | 0 – 522.24 | 75.37 *(82.83)* | 0 - 514.10 | 1316 | 65% *(37%)* | 0 - 100% |
| Vegetables | 29 | 1544 | 45.02 *(52.41)* | 0 - 514.10 | 25.53 *(41.11)* | 0 - 514.10 | 1112 | 55% *(38%)* | 0 - 100% |
| **Total FV** | 29 | 1544 | 164.45 *(119.61)* | 0 - 1028.19 | 102.00 *(102.76)* | 0 - 1028.19 | 1441 | 63% *(34%)* | 0 - 100% |

** = "FV percentage consumed" is reported only for students who served or were served more than 0 grams of fruits and vegetables*

**Table 4.9c. CAFES scales predictive validity subsample: Student FV servings, consumption, and percent consumed**

| | n Schools | n Students | FV served *(grams)* | | FV consumed *(grams)* | | n* | FV percentage consumed | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mean (*SD*) | Range | Mean (SD) | Range | | Mean (SD) | Range |
| ***TOTAL MEAL*** | | | | | | | | | |
| Fruits | 16 | 1069 | 118.52 *(85.67)* | 0 – 522.24 | 71.12 *(74.87)* | 0 - 514.10 | 929 | 62% *(38%)* | 0 - 100% |
| Vegetables | 16 | 1069 | 66.02 *(55.96)* | 0 – 527.41 | 38.56 *(46.49)* | 0 – 514.10 | 980 | 56% *(35%)* | 0 - 100% |
| **Total FV** | 16 | 1069 | 186.99 *(120.55)* | 0 - 1028.19 | 110.87 *(100.60)* | 0 - 1028.19 | 1042 | 61% *(32%)* | 0 - 100% |
| ***SIDE DISH*** | | | | | | | | | |
| Fruits | 16 | 1069 | 117.61 *(64.32)* | 0 – 522.24 | 70.66 *(74.25)* | 0 - 514.10 | 927 | 63% *(37%)* | 0 - 100% |
| Vegetables | 16 | 1069 | 45.64 *(45.77)* | 0 - 514.10 | 25.08 *(37.61)* | 0 - 514.10 | 857 | 52% *(37%)* | 0 - 100% |
| **Total FV** | 16 | 1069 | 165.26 *(111.77)* | 0 - 1028.19 | 96.65 *(94.68)* | 0 - 1028.19 | 1011 | 60% *(34%)* | 0 - 100% |

** = "FV percentage consumed" is reported only for students who served or were served more than 0 grams of fruits and vegetables*

Student level controls (grade, gender, BMI) were nested within school level CAFES scores and controls (CAFES total, four scales, or individual scale or subscale scores; percentage of FRPM students, percentage of minority students, urbanity, student population). Because more than 70% of parents did not report their child's gender or BMI, results including these controls are not displayed. As a result, little to no within-student variance was accounted for by any model, even though school-level variance components were significant for all models. Results of models including urbanity and student population are also not displayed because neither predictor was significant in any model. Furthermore, only results for combined FV outcomes, rather than individual FV outcomes, are presented.

*Parts A & B: Predictive validity of total CAFES scores and room, table, plate, and food scale scores*. Fully unconditional and partially conditional model results for Parts A (total CAFES score) and B (four CAFES scale scores) are displayed in Appendices C, D, and E. *Fully unconditional* results indicated significant differences in serving, consumption, and percent consumed for both total and side FV ($p$<0.05 for all $\gamma_{00}$ intercept coefficients), and that there was still unexplained variance in all six outcomes at the school level ($p$<0.05 for all school level $\mu_{0j}$ variance components). *Partially conditional* models, also with significant unexplained variance, included controls for student grade level, school level minority percentage, and school level FRPM participation percentage. *FRPM participation* was a significant predictor of total and side FV percentage consumed. A one percentage point increase in FRPM participation was associated with a 0.52% decrease in both total and side FV percentages consumed.

-*Part A*. Total CAFES score was a significant predictor in one of the Part A fully conditional models: *side FV percentage consumed*. Results are presented in Table 4.10.

***Table 4.10. Predictive validity: Fully conditional model with total CAFES score***

| | % SFV CONSUMED[a] | | Final estimation of fixed effects[a] | | | | |
|---|---|---|---|---|---|---|---|
| **Level** | **Fixed Effect** | *n*[b] | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
| *For Intercept,* $\beta_0$ | $\gamma_{00}$ Intercept | *29* | 0.18 | 0.22 | 0.83 | 25 | 0.416 |
| | $\gamma_{01}$ % FRPM | | -0.12 | 0.21 | -0.60 | 25 | 0.554 |
| | $\gamma_{02}$ % Minority | | -0.03 | 0.10 | -0.33 | 25 | 0.744 |
| | $\gamma_{03}$ **CAFES score** | | 0.92 | 0.42 | 2.17 | 25 | **0.040** |
| *For Grade,* $\beta_1$ | $\gamma_{10}$ Intercept | *1441* | 0.01 | 0.03 | 0.25 | 1514 | 0.806 |
| | | | Final estimation of variance components | | | | |
| | **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
| | Level 2 $\mu_{0j}$ | | 0.015 | 0.122 | 227.70 | 25 | **<0.001** |
| | Level 1 $r_{ij}$ | | 0.096 | 0.310 | | | |

***a**= with robust standard errors*
***b**= student level 1 and school level 2 sample sizes*
***c**= **Bolded p-value** indicates significance at the 0.05 alpha level*

***Table 4.11. Variance accounted for by total CAFES score and models***

| | Incremental variance: Partially Conditional[a] | | Incremental variance: Fully conditional[b] | | Total variance accounted for[c] | |
|---|---|---|---|---|---|---|
| **Outcome** | **% Within** *student level* | **% Between** *school level* | **% Within** *student level* | **% Between** *school level* | **% Within** *student level* | **% Between** *school level* |
| **SIDE FV** | | | | | | |
| **% SFV consumed** | 0.06 | 0.02 | 0.00 | 13.11 | 0.06 | 17.77 |

*a= Percent variance accounted for by controls: student grade level; % FRPM and % minority populations*
*b= Percent variance accounted for by room, table, plate, and food scale scores*
*c= Percent of the total variance accounted for by the fully conditional model (controls & predictors)*

An increase in total CAFES score was significantly associated with an increase in side FV percentage consumed when controlling for grade level, percent FRPM, and percent minority ($p$<0.05). Total CAFES score was not a significant predictor of any other outcome, but accounted for 13% of the between-school variance in percentage of side FV consumed (Table 4.11).

*-Part B*. At least one of the four scale scores was a significant predictor in five of the six Part 2 models. Results of the six models containing all four scale scores are presented in Tables 4.12a-f.

**Tables 4.12a-f. Predictive validity: Fully conditional models with CAFES scale scores** *(continued on next page)*

**a. FV SERVED**[a] — **Final estimation of fixed effects**[a]

| Level | Fixed Effect | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|---|
| *For Intercept, $\beta_0$* | $\gamma_{00}$ Intercept | *16* | 239.02 | 173.22 | 1.38 | 9 | 0.201 |
| | $\gamma_{01}$ **% FRPM** | | 212.12 | 68.58 | 3.09 | 9 | **0.013** |
| | $\gamma_{02}$ % Minority | | 125.70 | 79.70 | 1.58 | 9 | 0.149 |
| | $\gamma_{03}$ Room scale | | -200.27 | 167.49 | -1.20 | 9 | 0.262 |
| | $\gamma_{04}$ Table scale | | 129.88 | 203.29 | 0.64 | 9 | 0.539 |
| | $\gamma_{05}$ **Plate scale** | | 166.09 | 56.76 | 2.93 | 9 | **0.017** |
| | $\gamma_{06}$ Food scale | | -65.97 | 74.06 | -0.89 | 9 | 0.396 |
| *For Grade, $\beta_1$* | $\gamma_{10}$ Intercept | *1069* | 5.84 | 20.71 | 0.28 | 1052 | 0.778 |

**Final estimation of variance components**

| Random Effect | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 3858.30 | 62.12 | 281.29 | 9 | **<0.001** |
| Level 1 $r_{ij}$ | 9729.54 | 98.64 | | | |

**d. SFV SERVED**[a] — **Final estimation of fixed effects**

| Level | Fixed Effect | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|---|
| *For Intercept, $\beta_0$* | $\gamma_{00}$ Intercept | *16* | 44.44 | 144.65 | 0.31 | 9 | 0.77 |
| | $\gamma_{01}$ **% FRPM** | | 263.21 | 64.86 | 4.06 | 9 | **0.003** |
| | $\gamma_{02}$ % Minority | | 53.98 | 68.57 | 0.79 | 9 | 0.451 |
| | $\gamma_{03}$ Room scale | | -97.03 | 147.71 | -0.66 | 9 | 0.528 |
| | $\gamma_{04}$ Table scale | | 296.75 | 179.16 | 1.66 | 9 | 0.132 |
| | $\gamma_{05}$ **Plate scale** | | 122.94 | 47.55 | 2.59 | 9 | **0.029** |
| | $\gamma_{06}$ Food scale | | 28.12 | 64.71 | 0.44 | 9 | 0.674 |
| *For Grade, $\beta_1$* | $\gamma_{10}$ Intercept | *1069* | 7.82 | 16.43 | 0.48 | 1052 | 0.634 |

**Final estimation of variance components**

| Random Effect | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 2880.83 | 53.67 | 237.81 | 9 | **<0.001** |
| Level 1 $r_{ij}$ | 8287.70 | 91.04 | | | |

**b. FV CONSUMED**[a] — **Final estimation of fixed effects**[a]

| Level | Fixed Effect | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|---|
| *For Intercept, $\beta_0$* | $\gamma_{00}$ Intercept | *16* | -60.25 | 119.97 | -0.502 | 9 | 0.628 |
| | $\gamma_{01}$ % FRPM | | 10.33 | 74.69 | 0.138 | 9 | 0.893 |
| | $\gamma_{02}$ % Minority | | 32.91 | 60.95 | 0.540 | 9 | 0.602 |
| | $\gamma_{03}$ Room scale | | 29.32 | 115.60 | 0.254 | 9 | 0.805 |
| | $\gamma_{04}$ Table scale | | 261.49 | 194.46 | 1.345 | 9 | 0.212 |
| | $\gamma_{05}$ Plate scale | | 53.72 | 44.15 | 1.217 | 9 | 0.255 |
| | $\gamma_{06}$ Food scale | | 34.47 | 58.08 | 0.593 | 9 | 0.567 |
| *For Grade, $\beta_1$* | $\gamma_{10}$ Intercept | *1069* | 9.91 | 15.32 | 0.647 | 1052 | 0.518 |

**Final estimation of variance components**

| Random Effect | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 2125.01 | 46.10 | 171.08 | 9 | **<0.001** |
| Level 1 $r_{ij}$ | 8075.10 | 89.86 | | | |

**e. SFV CONSUMED**[a] — **Final estimation of fixed effects**

| Level | Fixed Effect | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|---|
| *For Intercept, $\beta_0$* | $\gamma_{00}$ Intercept | *16* | -187.22 | 105.33 | -1.78 | 9 | 0.109 |
| | $\gamma_{01}$ % FRPM | | 43.92 | 77.06 | 0.57 | 9 | 0.583 |
| | $\gamma_{02}$ % Minority | | -7.28 | 51.78 | -0.14 | 9 | 0.891 |
| | $\gamma_{03}$ Room scale | | 103.63 | 103.99 | 1.00 | 9 | 0.345 |
| | $\gamma_{04}$ **Table scale** | | **356.15** | **176.25** | **2.02** | **9** | **0.074**[d] |
| | $\gamma_{05}$ Plate scale | | 26.81 | 37.22 | 0.72 | 9 | 0.490 |
| | $\gamma_{06}$ Food scale | | 98.17 | 54.96 | 1.79 | 9 | 0.108 |
| *For Grade, $\beta_1$* | $\gamma_{10}$ Intercept | *1069* | 10.72 | 11.72 | 0.92 | 1052 | 0.360 |

**Final estimation of variance components**

| Random Effect | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 1695.28 | 41.17 | 148.32 | 9 | **<0.001** |
| Level 1 $r_{ij}$ | 7129.36 | 84.44 | | | |

***a****= with robust standard errors*
***b****= student level 1 and school level 2 sample sizes*
***c****= **Bolded p-value** indicates significance at the 0.05 alpha level*
***d****= Significant at the 0.10 alpha level*

### *Tables 4.12a-f. Predictive validity: Fully conditional models with CAFES scale scores (continued)*

**c. FV % CONSUMED[a]** — **Final estimation of fixed effects[a]**

| Level | Fixed Effect | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value[c]* |
|---|---|---|---|---|---|---|---|
| *For Intercept, $\beta_0$* | $\gamma_{00}$ Intercept | *16* | -0.45 | 0.31 | -1.46 | 9 | 0.179 |
| | $\gamma_{01}$ % FRPM | | -0.45 | 0.21 | -2.11 | 9 | 0.064[d] |
| | $\gamma_{02}$ **% Minority** | | -0.35 | 0.14 | -2.61 | 9 | **0.029** |
| | $\gamma_{03}$ **Room scale** | | 0.57 | 0.22 | 2.57 | 9 | **0.030** |
| | $\gamma_{04}$ **Table scale** | | 1.26 | 0.41 | 3.05 | 9 | **0.014** |
| | $\gamma_{05}$ **Plate scale** | | -0.23 | 0.06 | -3.66 | 9 | **0.005** |
| | $\gamma_{06}$ **Food scale** | | 0.40 | 0.12 | 3.43 | 9 | **0.007** |
| *For Grade, $\beta_1$* | $\gamma_{10}$ Intercept | *1042* | 0.02 | 0.03 | 0.52 | 1052 | 0.607 |

**Final estimation of variance components**

| Random Effect | *Variance component* | *SD* | *$X^2$* | *d.f.* | *p-value[c]* |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 0.012 | 0.110 | 92.03 | 9 | **<0.001** |
| Level 1 $r_{ij}$ | 0.080 | 0.283 | | | |

**f. SFV % CONSUMED[a]** — **Final estimation of fixed effects**

| Level | Fixed Effect | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value[c]* |
|---|---|---|---|---|---|---|---|
| *For Intercept, $\beta_0$* | $\gamma_{00}$ Intercept | *16* | -0.61 | 0.30 | -2.03 | 9 | 0.073 |
| | $\gamma_{01}$ % FRPM | | -0.48 | 0.21 | -2.25 | 9 | 0.051[d] |
| | $\gamma_{02}$ **% Minority** | | -0.34 | 0.12 | -2.83 | 9 | **0.020** |
| | $\gamma_{03}$ **Room scale** | | 0.72 | 0.21 | 3.48 | 9 | **0.007** |
| | $\gamma_{04}$ **Table scale** | | 1.34 | 0.37 | 3.58 | 9 | **0.006** |
| | $\gamma_{05}$ **Plate scale** | | -0.24 | 0.05 | -5.31 | 9 | **<0.001** |
| | $\gamma_{06}$ **Food scale** | | 0.44 | 0.12 | 3.57 | 9 | **0.006** |
| *For Grade, $\beta_1$* | $\gamma_{10}$ Intercept | *1011* | 0.03 | 0.03 | 0.81 | 1052 | 0.416 |

**Final estimation of variance components**

| Random Effect | *Variance component* | *SD* | *$X^2$* | *d.f.* | *p-value[c]* |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 0.011 | 0.105 | 75.94 | 9 | **<0.001** |
| Level 1 $r_{ij}$ | 0.091 | 0.301 | | | |

***a**= with robust standard errors*
***b**= student level 1 and school level 2 sample sizes*
***c**= **Bolded p-value** indicates significance at the 0.05 alpha level*
***d**= Significant at the 0.10 alpha level*

### *Table 4.13. Variance accounted for by models with CAFES scale scores*

| Outcome | **Incremental variance: Partially Conditional[a]** | | **Incremental variance: Fully conditional[b]** | | **Fully conditional variance[c]** | |
|---|---|---|---|---|---|---|
| | **% Within** (*student level*) | **% Between** (*school level*) | **% Within** (*student level*) | **% Between** (*school level*) | **% Within** (*student level*) | **% Between** (*school level*) |
| **TOTAL MEAL** | | | | | | |
| FV served | -0.03 | -2.67 | 0.01 | 9.84 | -0.04 | 12.51 |
| FV consumed | 0.14 | -9.41 | -0.01 | -4.29 | 0.13 | -5.12 |
| **FV % consumed** | -0.01 | 26.12 | 0.00 | 17.77 | -0.01 | 43.89 |
| **SIDE DISH** | | | | | | |
| FV served | 0.05 | 9.35 | -0.01 | 21.62 | 0.04 | 30.97 |
| FV consumed | 0.23 | -11.43 | -0.01 | 0.72 | 0.21 | 12.15 |
| **FV % consumed** | 0.11 | 22.78 | -0.03 | 26.26 | 0.08 | 49.04 |

[a] *= Percent variance accounted for by controls: student grade level; % FRPM and % minority populations*
[b] *= Percent variance accounted for by room, table, plate, and food scale scores*
[c] *= Percent of the total variance accounted for by the fully conditional model (controls & predictors)*

An increase in plate scale score was significantly associated with an increase in *total FV* and *side FV served* (Tables 4.12a & 4.12d) when controlling for all other variables in the model ($p<0.05$). No CAFES scale scores significantly predicted *total FV consumed* (Table 4.12b), but a one percentage point increase in table scale score was marginally associated with a 3.56 gram increase in *side FV consumed* (Table 4.12e; $p<0.10$). All scale scores were significant predictors of the *total* and *side FV percentages consumed* (Tables 4.12c & 4.12f; $p<0.05$). One percentage point increases in room, table, and food scale scores were associated with 0.57%, 1.26%, and 0.40% increases in *total FV percentage consumed* (Table 4.12c, $p<0.05$). A one percentage point increase in plate scale score, however, was associated with a 0.23% decrease in total FV percentage consumed ($p<0.05$). Similarly, percentage point increases in room, table, and food scale scores were associated with 0.72%, 1.34%, and 0.44% increases in side FV percentage consumed (Table 4.12f; $p<0.05$). An increase in plate scale score was associated with a 0.24% decrease in side FV percentage consumed. Higher percentages of both *FRPM students* (marginally significant, $p<0.10$) and *minority students* (significant, $p<0.05$) were also associated with 0.02% - 0.06% increases in percentages of total and side FV consumed (see Tables 4.12c & 4.12f).

*Control variables* (student grade level, percent FRPM, and percent minority population), displayed in Table 4.13, included in partially conditional models accounted for 3% - 26% of the variance in total FV outcomes and 9% - 23% of the variance in side FV outcomes between schools.[46] The *four CAFES scale scores* in fully conditional models, also presented in Table 4.13, accounted for an additional 4% - 18% of the variance in total FV outcomes and 1% - 26% of the variance in side FV outcomes between schools. Finally, total and side FV percentages consumed models accounted for a total of 44% and 49% of the total school-level variance, respectively. All models accounted for nearly zero variance within students (0.01% – 0.23%).

[46] A negative percent variance indicates an inverse relationship between predictors and outcomes.

*Part C: Individual scale and subscale scores*. In order to examine the predictive validity of individual scales and subscales, each individual scale score was entered into all six models, as well as each individual room and table scale subscale scores. All room scale subscales and all table scale subscales were also entered simultaneously to see if significant effects remained while controlling for all other subscales. A summary of the significant results is presented in Tables 4.14a-c. Complete subscale analyses results, which consist of 39 tables, are not included in order to conserve space. Instead, only estimates for each significant predictor are presented here. School level variance components were significant in all models.

***Table 4.14a. FV served results, controlling for % FRPM, % minority, and grade level***

| **CAFES Score** (total # schools) | **FV served** | | | | **SFV served** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Est** | **SE** | **t-test results** | **n**[n] | **Est** | **SE** | **t-test results** | **n**[n] |
| **TOTAL** (29) | n/a | | | | n/a | | | |
| **4 SCALES** (16) | n/a | | | | n/a | | | |
| **Room scale** (30) | n/a | | | | n/a | | | |
| *Ambient* (22) | n/a | | | | n/a | | | |
| *Appearance* (29) | n/a | | | | n/a | | | |
| *Fenestration* (28) | n/a | | | | n/a | | | |
| *Layout (29)* | 141.86 | *(53.29)* | *t*(25)= 2.66[a] | 29, 1651 | 122.91 | *(55.99)* | *t*(25)= 2.20[a] | 29, 1651 |
| *Ads* (29) | n/a | | | | n/a | | | |
| *Kitchen & Serving* (30) | n/a | | | | 264.99 | *(130.24)* | *t*(11)= 2.04[d] | 19, 991 |
| **Table scale** (25) | n/a | | | | n/a | | | |
| *Furniture* (29) | n/a | | | | n/a | | | |
| *Availability* (29) | n/a | | | | n/a | | | |
| *Display* (28) | -143.97 | *(60.54)* | *t*(24)= -2.38[a] | 28, 1534 | -145.01 | *(64.38)* | *t*(24)= -2.25[a] | 28, 1534 |
| *Serving method* (27) | -343.10<br>-386.61 | *(125.66)*<br>*(171.62)* | *t*(23)= -2.73[a]<br>*t*(12)= -2.25[b] | 27, 1520<br>20, 1037 | -348.37<br>-389.57 | *(124.64)*<br>*(167.72)* | *t*(23)= -2.80[a]<br>*t*(12)= -2.32[b] | 27, 1520<br>20, 1037 |
| *Variety* (29) | n/a | | | | n/a | | | |
| **Plate scale** (27) | *104.83* | *(39.84)* | *t*(23)= 2.63[a] | 27, 1618 | 100.12 | *(34.19)* | *t*(23)= 2.93[a] | 27, 1618 |
| | See Table 4.12a[b] | | | | See Table 4.12d[b] | | | |
| **Food scale** (21) | n/a | | | | n/a | | | |

[a] = *Significant at the 0.05 alpha level*
[b] = *Significant at the 0.05 alpha level when entered with other three scale or subscale scores*
[c] = *Marginally significant (p<0.10)*
[d] = *Marginally significant (p<0.10) when entered with other three scale or subscale scores*
n/a = *Not significant (p≥0.10)*
n = *School sample size, student sample size*

The “total score” and “4 scale” rows in Tables 4.14a-c summarize analysis Parts A and B results. The remaining rows indicate individual CAFES scale and subscale scores that significantly predicted a FV outcome. In Table 4.14a, for example, the *room scale layout* subscale significantly predicted the amount of FV and side FV served ($p<0.05$), but the effect was not significant when entered with other room scale subscales. The *kitchen and serving area* subscale score was also marginally associated with an increase in side FV served ($p<0.10$). Among the table scale subscales, *display* (alone) and *serving method* (with and without other table scale subscales) subscales were associated with decreases in FV and side FV served ($p<0.05$). *Plate scale* was also a significant predictor of FV and side FV served when entered with and without the other three scale scores. Table 4.14b summarizes the results of FV *consumption* outcomes.

***Table 4.14b. FV consumed results, controlling for % FRPM, % minority, and grade level***

| **CAFES Score** (total # schools) | **FV consumed** | | | | **SFV consumed** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Est** | **SE** | **t-test results** | **n**[n] | **Est** | **SE** | **t-test results** | **n**[n] |
| **TOTAL** (29) | n/a | | | | n/a | | | |
| **4 SCALES** (16) | n/a | | | | n/a | | | |
| **Room scale** (30) | n/a | | | | n/a | | | |
| *Ambient* (22) | n/a | | | | n/a | | | |
| *Appearance* (29) | n/a | | | | n/a | | | |
| *Fenestration* (28) | n/a | | | | n/a | | | |
| *Layout (29)* | n/a | | | | n/a | | | |
| *Ads* (29) | n/a | | | | n/a | | | |
| *Kitchen & Serving* (30) | 127.49<br>173.94 | *(51.54)*<br>*(87.62)* | $t(23)= 2.47$[a]<br>$t(11)= 1.99$[d] | 30, 1613<br>19, 991 | 130.82<br>171.19 | *(47.22)*<br>*(82.54)* | $t(26)= 2.77$[a]<br>$t(11)= 2.07$[d] | 30, 1613<br>19, 991 |
| **Table scale** (25) | n/a | | | | 356.15 | *(176.25)* | $t(9)= 2.02$[d] | 16,1069 |
| *Furniture* (29) | n/a | | | | n/a | | | |
| *Availability* (29) | 292.85 | *(162.89)* | $t(12)= 1.80$[d] | 20, 1037 | -- | | | |
| *Display* (28) | -103.83 | *(46.16)* | $t(24)= -2.25$[a] | 28, 1534 | -102.05 | (*50.14*) | $t(24)= -2.04$[a] | 28, 1534 |
| *Serving method* (27) | -267.97<br>-258.13 | *(74.90)*<br>*(112.24)* | $t(23)= -3.58$[a]<br>$t(12)= -2.30$[b] | 27, 1520<br>20, 1037 | -267.56<br>-244.84 | *(77.34)*<br>*(114.16)* | $t(23)= -3.46$[a]<br>$t(12)= -2.15$[b] | 27, 1520<br>20, 1037 |
| *Variety* (29) | n/a | | | | n/a | | | |
| **Plate scale** (27) | 63.40 | *(27.10)* | $t(23)= 2.34$[c] | 27, 1618 | 61.78 | *(22.40)* | $t(23)= 2.76$[c] | 27, 1618 |
| **Food scale** (21) | n/a | | | | n/a | | | |

[a] = *Significant at the 0.05 alpha level*
[b] = *Significant at the 0.05 alpha level when entered with other three scale or subscale scores*
[c] = *Marginally significant ($p<0.10$)*
[d] = *Marginally significant ($p<0.10$) when entered with other three scale or subscale scores*
n/a = *Not significant ($p \geq 0.10$)*    n= *school sample size, student sample size*

Within the room scale subscales, increases in only the *kitchen and serving area* scores, entered with (*p*<0.10, marginally significant) and without (*p*<0.05, significant) other room scale subscales, were significantly associated with increases in FV and side FV consumed. Increases in the *table scale availability* subscale score were marginally associated with increases in FV consumed when controlling for other table scale subscales (*p*<0.10). Contrary to expectations, decreases in *table scale display* (alone) and *serving method* (with and without other table scale subscales) scores were associated with increases in both FV and side FV consumption (*p*<0.05). Increases in *plate scale* scores were significantly associated with increases in FV and side FV consumption (*p*<0.05). Table 4.14c summarizes the remaining analysis of FV percentage consumed outcomes.

***Table 4.14c. FV % consumed results, controlling for % FRPM, % minority, and grade level***

| **CAFES Score** (total # schools) | **FV % consumed** | | | | **SFV % consumed** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Est** | **SE** | **t-test results** | **n**[n] | **Est** | **SE** | **t-test results** | **n**[n] |
| **TOTAL** (29) | n/a | | | | See Table 4.10[a] | | | |
| **4 SCALES** (16) | See Table 4.12c[a] | | | | See Table 4.12f[a] | | | |
| **Room scale** (30) | See Table 4.12c[b] | | | | See Table 4.12f[b] | | | |
| *Ambient* (22) | n/a | | | | n/a | | | |
| *Appearance* (29) | n/a | | | | n/a | | | |
| *Fenestration* (28) | n/a | | | | n/a | | | |
| *Layout (29)* | -0.23<br>-0.35 | *(0.10)*<br>*(0.15)* | *t*(25)= -2.30[a]<br>*t*(11)= -2.26[b] | 29, 1575<br>19, 991 | -0.25<br>-0.38 | *(0.11)*<br>*(0.16)* | *t*(25)= -2.35[a]<br>*t*(10)= -2.31[d] | 29, 1528<br>19, 991 |
| *Ads* (29) | -0.19 | *(0.03)* | *t*(25)= -5.95[a] | 29, 1538 | -0.20<br>-0.15 | *(0.03)*<br>*(0.08)* | *t*(25)= -5.84[a]<br>*t*(10)= -1.86[b] | 29,1492<br>19, 991 |
| *Kitchen/Serve* (30) | 0.52 | *(0.18)* | *t*(26)= 2.93[a] | 29, 1547 | 0.53 | *(0.18)* | *t*(26)= 2.94[a] | 20, 1506 |
| **Table scale** (25) | 0.77 | *(0.29)* | *t*(25)= 2.68[a] | 25, 1478 | 0.87 | *(0.28)* | *t*(25)= 3.13[a] | 25, 1441 |
| | See Table 4.12c[b] | | | | See Table 4.12f[b] | | | |
| *Furniture* (29) | n/a | | | | n/a | | | |
| *Availability* (29) | 0.51 | *(0.28)* | *t*(25)= 1.80[c] | 29, 1478 | 0.51 | *(0.29)* | *t*(25)= 1.77[c] | 29, 1441 |
| *Display* (28) | n/a | | | | n/a | | | |
| *Serving method* (27) | n/a | | | | n/a | | | |
| *Variety* (29) | 0.24 | *(0.10)* | *t*(25)= 2.39[a] | 29, 1478 | 0.27 | *(0.10)* | *t*(25)= 2.63[a] | 29, 1441 |
| **Plate scale** (27) | See Table 4.12c[b] | | | | See Table 4.12f[b] | | | |
| **Food scale** (21) | See Table 4.12c[b] | | | | See Table 4.12f[b] | | | |

[a] = *Significant at the 0.05 alpha level*
[b] = *Significant at the 0.05 alpha level when entered with other three scale of subscale scores*
[c] = *Marginally significant (p<0.10)*
[d] = *Marginally significant (p<0.10) when entered with other three scale or subscale scores*
n/a = *Not significant (p≥0.10)* n= *school sample size, student sample size*

*Total CAFES* score, the *four scale* scores, and individual *room*, *table*, *plate*, *food scale* scores were significant predictors of both total and side FV percentage consumed as presented in Tables 4.12A-F. Increases in room scale *layout* (with and without other subscales) and *advertising* (alone) subscale scores were associated with decreases in total and side FV percentage consumed ($p$<0.05). *Kitchen and serving area* subscale scores ($p$<0.05), along with table scale *availability* ($p$<0.10) and *variety* ($p$<0.05) subscale scores were also associated with increases in total FV and side FV percentages consumed.

## DISCUSSION

### ***Strengths***

CAFES is the first assessment instrument focused on the physical environment within school cafeterias as it relates to healthy eating. CAFES contributes to the development of a method to evaluate existing school cafeterias, and to future standardized guidelines, based on behavioral economics and environmental psychology, that promote healthy and discourage unhealthy eating. Furthermore, results revealed that CAFES is a generally valid and reliable (with the exception of the food scale) objective measure of the physical elementary school cafeteria environment. A broad range of environmental attributes and affordances within elementary school cafeterias, relevant to diet, were represented within the four scales and subscales. CAFES was pilot tested by both trained researchers and Extension Educators with only written instructions and proved to be a practical, easy-to-use, and fairly inexpensive assessment tool for measuring environmental supports of and barriers to the selection and consumption of FV in elementary school cafeterias. Future observers can be trained in person or via written instructions to use written or online CAFES versions. By focusing explicitly on elementary schools, NSLP participants, and FRPM recipients, CAFES scores highlight specific areas on which to focus low- and no-cost intervention strategies that can immediately be implemented to especially benefit high risk and underserved FRPM student populations.

### *Results summary: CAFES development, reliability, and validity*

A summary of CAFES reliability testing, predictive validity results, and agreement with previous literature is presented in Table 4.15. CAFES limitations, implications, applications, and future work are then discussed.

***Table 4.15. CAFES reliability and predictive validity results summary***
*(Controlling for % FRPM, % Minority, and Student Grade Level)*

| | FV Served | | FV Consumed | | FV % Consumed | |
|---|---|---|---|---|---|---|
| **CAFES Score*** | **FV** | **SFV** | **FV** | **SVF** | **FV** | **SFV** |
| **TOTAL SCORE*** | -- | -- | -- | -- | -- | $X^{+a}$ |
| **4 SCALES** | -- | -- | -- | -- | $X^{a}$ | $X^{a}$ |
| **Room scale*** | -- | -- | -- | -- | $X^{+b}$ | $X^{+b}$ |
| *Ambient** | -- | -- | -- | -- | -- | -- |
| *Appearance** | -- | -- | -- | -- | -- | -- |
| *Fenestration** | -- | -- | -- | -- | -- | -- |
| *Layout** | $X^{+a}$ | $X^{+a}$ | -- | -- | $X^{-a, -b}$ | $X^{-a, -d}$ |
| *Ads* | -- | -- | -- | -- | $X^{-a}$ | $X^{-a, -b}$ |
| *Kitchen/Serve** | -- | $X^{+d}$ | $X^{+a, +d}$ | $X^{+a, +d}$ | $X^{+a}$ | $X^{+a}$ |
| **Table scale*** | -- | -- | -- | $X^{+d}$ | $X^{+a, +b}$ | $X^{+a, +b}$ |
| *Furniture* | -- | -- | -- | -- | -- | -- |
| *Availability** | -- | -- | $X^{+d}$ | -- | $X^{+c}$ | $X^{+c}$ |
| *Display** | $X^{-a}$ | $X^{-a}$ | $X^{-a}$ | $X^{-a}$ | -- | -- |
| *Serving method* | $X^{-a, -b}$ | $X^{-a, -b}$ | $X^{-a, -b}$ | $X^{-a, -b}$ | -- | -- |
| *Variety** | -- | -- | -- | -- | $X^{+a}$ | $X^{+a}$ |
| **Plate scale*** | $X^{+a, +b}$ | $X^{+a, +b}$ | $X^{+c}$ | $X^{+c}$ | $X^{-b}$ | $X^{-b}$ |
| **Food scale** | -- | -- | -- | -- | $X^{+b}$ | $X^{+b}$ |

$X^{a}$ = *Significant at the 0.05 alpha level*
$X^{b}$ = *Significant at the 0.05 alpha level when entered with other three scale or subscale scores*
$X^{c}$ = *Marginally significant (p<0.10)*
$X^{d}$ = *Marginally significant (p<0.10) when entered with other three scale or subscale scores*
+/- = *Indicates positive (+) or negative (-) association between predictor and outcome*
-- = *Not significant (p>0.10)*
* = *Scale or subscale was internally consistent (KR-21 $\geq$ 0.70)*
= *Predictive validity results agreed with prior studies reviewed in the introduction*

*Total CAFES score.* Although the overall CAFES assessment instrument was generally reliable, total CAFES scores only significantly predicted side FV percentage consumed. *FV serving* outcomes were likely not significantly predicted by total CAFES scores because serving-specific outcomes were associated with serving area-specific CAFES items. Low variability in total CAFES scores may also partially explain the lack of significance in predicting other outcomes. The 51% average total CAFES score (range of 35% - 64%) suggested that all schools in this sample could benefit from additional environmental supports of healthy eating behaviors. An increase of only one percentage point in total CAFES score, however, was associated with an average 0.92% increase in side FV percentage consumed (1.62 grams of FV on average) when controlling for student grade level, percent school minority population, and percent school FRPM participation. Although the inclusion of student level BMI and gender may weaken this association, results offer promising empirical evidence that elements of the physical cafeteria environment across the four scales influenced consumption of side FV.

*CAFES room, table, plate, and food scales.* Room, table, plate, and food scale scores, when entered simultaneously into multi-level models, all significantly predicted total and side FV percentages consumed. Associations were positive for room, table, and food scale scores, but negative for plate scale scores. This negative association can be attributed to the "styrofoam tray" meals and CAFES variable coding. In this analysis, smaller trays were coded with a "1" and not a "0," based on previous research that found an association between larger plate and bowl sizes and increased intake among adults (Sobal & Wansink, 2007; Wansink & Cheney, 2005). Based on CAFES data, however, the smaller styrofoam trays were too small and weak for students to easily handle. Larger plastic trays were more appropriate for young students to carry and balance items while obtaining food. Coding was therefore reversed in the final CAFES version so that smaller trays sizes were coded with a "0." One percentage point increases in table scale scores were associated with the largest increases in total and side FV percentages consumed (1.26% and 1.34%), followed by room scale (0.57% and 0.72%), and food scale (0.40% and 0.44%).

*FRPM participation and minority student population*. Although an increase in the percentage of FRPM students was associated with an increase in total and side FV *served*, one percentage point increases in minority student population were associated with more than 0.30% reductions in the total and side FV percentage *consumed*. This suggested that schools with higher participation in FRPM served more FV, which is consistent with literature reporting that school districts with greater FRPM populations have stronger wellness policies and that FRPM meals have better nutritional content (Mancino & Guthrie, 2009; Story, Nanney, & Schwartz, 2009). Variations in physical environment affordances captured by CAFES items, food quality, food preferences, role modeling, or nutrition education (Gorman et al., 2007; Swanson et al., 2009) however, may contribute to lower FV percentages consumed in schools with larger percentages of minority students. Reliability and predictive validity results of individual scales and subscales are discussed in the following sections.

*Individual CAFES scales and subscales:*

*Room scale*. Few studies have examined the relationship between the room scale and FV outcomes among children or school cafeteria settings. Because changing attributes within the room scale such as ventilation systems, floor plans, and natural and artificial lighting can be expensive, the fact that CAFES schools scored highest, on average, at this scale implied that CAFES schools could benefit from numerous lower cost interventions aimed at other scales. Increases in room scale scores, when entered with table, plate, and food scales, were significantly associated with increases in total and side FV percentages consumed. This was expected considering that, with the exception of kitchen and serving area subscale items, room scale items focused on the cafeteria *eating* (vs. serving or preparation) environment. Although CAFES room scale items met the 0.70 KR-21 criteria for internal consistency, several room scale items were challenging to objectively and reliably code, especially considering that many CAFES observations excluded students and food. Significant correlations between the overall room scale score and appearance, fenestration, layout, and kitchen and serving area subscales, but not ambient environment subscale, suggested that the ambient environment subscale especially may have suffered from a lack of objective measures as well as low variability.

Contrary to prior studies (Herman, 1993; Stroebele & de Castro, 2004, 2006; Wansink, 2004; Chandon & Wansink, 2011; Mancino & Guthrie, 2009; Sobal & Wansink, 2007; Rozin, 2009), the *cafeteria ambient environment* did not significantly predict any FV outcomes among the CAFES sample even though it was an internally consistent subscale (KR-21≥0.70). Low variability may have contributed to the lack of significant results. Moreover, studies linking ambient environmental characteristics to consumption were primarily conducted among adults who control the length of their meal time and whether or not to order or serve themselves additional food (Stroebele & de Castro, 2004; Wansink, 2004; Wansink & Van Ittersum, 2012). Given fixed meal times, often fixed meal options, and fixed portion sizes, the effects of the ambient environment on FV servings and consumption likely differed among CAFES elementary school cafeteria students when compared to adults dining in restaurants or college students in cafeterias. Further studies are needed to determine how ambient characteristics may affect elementary student FV outcomes within meal time constraints, as well as whether children's perceptions of ambient conditions affect FV servings and consumption.

Additionally, a more varied CAFES sample and more objective measures of the cafeteria ambient environment were needed, as well as observations during meal times when children, staff, and food were present. Photos from Extension Educators used to code some ambient environment items varied in quality, making it difficult to consistently rate, for example, lighting conditions. Ideally, objective temperature, lighting, and noise data should be gathered using a thermostat, lux meter, and decibel meter. The presence of sound dampening materials or lunchtime policies to control noise[47] could also be recorded as part of the room scale. Furthermore, the effects of crowding may be moderated by room layout, circulation, or meal time procedures (e.g., dismissing one table at a time vs. all), but could not be captured during CAFES observations with no students present.

[47] E.g., as cafeteria noise levels rose in one WA school, teachers were observed clapping in a pattern which students were then expected to repeat, signaling that they were listening and knew to lower their voices.

Although *cafeteria and serving area appearance* and *cafeteria fenestration* subscale items were internally consistent (KR-21$\geq$0.70), they too did not significantly predict any FV outcomes.  A more varied sample and more objective measures were also needed for these room scale subscales, as well as an understanding of how children's perceptions of both appearance and fenestration may or may not affect FV consumption.  While previous studies found that appearance and fenestration contribute to the room scale and affect eating behaviors among adults (Sobal & Wansink, 2007), design attributes such as color, proportion, decoration (e.g., student artwork, school spirit décor) and surface materials thought to affect students dining in school cafeterias (Gorman et al., 2007) were not included among room scale appearance items due to a lack of empirical research linking these items to elementary students' eating behaviors.  Although fenestration emerged as a reliable and consistent subscale, the eight moderately correlated fenestration items "weighted" cafeteria windows more heavily than other individual ambient and appearance subscale items.  Considering the lack of research on the association between day lighting, natural light, window views, and eating behaviors, one or two combined fenestration scores (e.g., presence of windows and a combined window condition score) incorporated into the appearance or ambient room scale subscales may be more conceptually appropriate than a separate cafeteria fenestration subscale.

*Cafeteria layout and visibility*, which also met internal consistency criterion, significantly predicted four outcomes: total FV served, side FV served, total FV percentage consumed, and side FV percentage consumed.  An increase in layout subscale score was associated with a significant increase in total and side FV served, but also a decrease in total and side percentages consumed.  Better layouts likely promoted better actual and perceived access (e.g., better circulation and more time), visibility (e.g., fewer obstructions), and convenience (e.g., less effort to obtain food) of foods associated with increases in FV servings as found in prior studies (Painter et al., 2002; Story et al., 2006; Wansink et al., 2006), but a more varied sample is needed.  Because students in schools with higher layout and visibility subscale scores were either served or served themselves significantly more FV, that may partially explain why they consumed a smaller percentage of the overall servings. In addition to better layout and visibility, whether or not students had a choice of FV served or were allowed to serve themselves may also have contributed to the larger FV serving sizes. Elementary school students who serve themselves typically over-serve and have difficulty judging appropriate portion sizes (Van Ittersum & Wansink, 2007). Conducting CAFES observations during meal times could reveal why the association between FV percentage consumed outcomes and the layout and visibility subscale was negative.

Due to missing data and low variability, only one *advertising and signage subscale* item was included in CAFES analysis for this sample. Although an increase in healthy signage was associated with a decrease in total and side FV percentages consumed contrary to prior studies (French et al., 2001; Hayne et al., 2004), single items cannot be used as reliable measures of a construct. A plausible explanation for the negative association, however, may be that schools with more students who struggle to serve and consume enough FV were more likely to post healthy signage. Additional research is needed to evaluate how the presence, quantity, and location of healthy and unhealthy signage affect elementary school students' eating behaviors. Establishing the most effective location and placement to encourage FV servings and consumption would offer another low-cost intervention suggestion to school staff.

*Kitchen and serving area* subscale items, which also met internal consistency criterion, were separated from other room scale subscales because they were often separate spaces and directly related to FV serving outcomes. This subscale significantly predicted side FV served, total and side FV consumed, and total and side FV percentages consumed. Although no research explicitly links these kitchen and serving area items to FV servings, other research linking room scale items to servings suggests that the availability of equipment, storage space, display space, appearance, and condition of the kitchen and serving area likely affected the availability, perceived and actual access, visibility, convenience, attractiveness, and presentation of FV (Sobal & Wansink, 2007; Mancino & Guthrie, 2009). This subscale may also have served as an indicator of school-level policies, resources, and abilities to offer healthy, appealing, and good quality food and beverage options to students. A complete, objective inventory of kitchen and serving areas was not included in CAFES beyond asking food service staff about items that supported or limited offering healthy options. Assessing available square footage, equipment, and layout of preparation and serving areas could further identify differences between school environments with varying FV offerings and outcomes.

*Table scale.* Overall, average *table scale* scores were lower than any other scale score. Averaging only 43%, schools in the CAFES sample would benefit most from table scale interventions. Most table scale items, all of which were internally consistent, were collected from food service staff interviews and not during CAFES observations to document the average or typical table scale and not just the table scale during observation or lunch tray photography. The “table scale” in school cafeterias may be more appropriately termed “counter scale,” with the exception of the cafeteria furniture subscale. Factors that affect the selection and serving of food conceptually differ from those that affect the consumption of food at the table within eating areas. Significant increases in table scale scores were associated with increases in side FV consumed, and total and side FV percentages consumed, consistent with prior research (see Sobal & Wansink, 2007; Chandon & Wansink, 2011). The positive associations were likely attributed to availability and variety subscale items. The positively skewed[48] and leptokurtic[49] table scale data, however, indicated that a more varied sample was needed.

The cafeteria *furniture* subscale was the least internally consistent CAFES subscale. The furniture subscale did not significantly predict any FV outcome contrary to prior studies

[48] More lower scores and a longer positive tail than a normal distribution.
[49] Peaked relative to a normal distribution.

(Sobal & Wansink, 2007; Mancino & Guthrie, 2009), which further suggests that items should be omitted or combined with the room scale appearance subscale. Cafeteria furniture subscale items described the tables and chairs students used during meal times, while all other table scale subscale items pertained to serving areas. Additionally, without observing actual meal periods, observers found it difficult to assess whether or not furniture size, shape, or seating type affected students' eating behaviors. All cafeterias in this sample used various standard cafeteria tables and seating that facilitated quick set-up, removal, and cleaning, but CAFES schools could be compared to schools that offer more domestic or alternative furniture options. Lunch room policies could also affect interaction with furniture, such as requiring assigned seats or tables, especially when one space contains different types of furniture (e.g., some students sit at round tables with individual seats while others are required to sit at rectangular tables with attached benches). Empirical rather than anecdotal evidence is needed to further examine the relationship between cafeteria furniture and elementary students' eating behaviors.

The table scale contained the highest number of CAFES items due to the *availability* subscale, which met the internal consistency criterion. Most of the availability items were recorded during food service staff interviews and not CAFES observations. The weighted[50] availability subscale was appropriate given that availability and access to healthy foods is one of the top predictors of consumption (Story et al., 2008). Availability, accordingly, significantly predicted FV consumption: increases in availability subscale scores were associated with significant increases in total FV consumed, total FV percentage consumed, and side FV percentage consumed. FV serving outcomes were surprisingly not associated with availability; however, whether students were offered a choice of FV items and whether or not schools used the "offer versus serve" serving method could have confounded the availability and serving outcome relationship. Availability subscale results, however,

[50] Six items – one for each of 0-5 lunch meals per week - were created for each availability subscale item.

confirmed previous findings that availability alone is not enough to increase FV selection (Swanson et al., 2009).

<u>*Display layout & presentation*</u> and <u>*serving method*</u> subscale items suffered from low variability, which may have partially explained their significantly negative associations with total and side FV served *and* consumed. Creative displays, attractive presentation, layout of foods, and food serving methods were expected to be associated with increases in FV outcomes based on prior work. In addition to low variability, schools with higher display and serving method subscale scores may not have offered choices or variety to their students, or students declined to be served FV if given a choice. Items from both subscales were also difficult to code when food and beverages were absent during observations and from photographs, which also likely contributed to the negative association.

The display layout and presentation subscale, which was internally consistent, may also have been measuring two constructs that should be separated and not combined: the order of items in the display and milk location may have been more related to physical placement while menu naming, individual item labeling, and presentation attractiveness assessed how items are presented. Several items were also omitted from these two subscales, but included in the final version of CAFES, due to a lack of variability: whether any food and beverage items were located out of reach and accessible by request only (display layout), and whether multiple serving trips were allowed (serving method). CAFES observations also led to the addition of a CAFES item to capture the presence of a sharing table discussed in the *Results* section.

The serving method subscale did *not* meet the internal consistency criterion. Food item packaging and serving vessel variables were especially difficult to code when food and beverage items were absent during observations and from photographs. Items were also not assessed for each food type offered in the serving area (e.g., is the offer vs. serve method used for all items or only FV). Additionally, serving method subscale items - tray and tray rest availability, food packaging, verbal prompts, and whether students were allowed to serve themselves for various items - may have been measuring multiple constructs related to serving and consumption that needed to be separate subscales with additional items (e.g., convenience, visual cues, prompts, and choice). Although obtaining table scale items from food service staff interviews provided a better indication of the average table scale than a one-time observation when students and food were not present, it may have resulted in discrepancies between that data, CAFES observations, and lunch tray photography data. This also could have partially accounted for negative associations between subscale scores and FV outcomes. Further investigation is needed to explain why display, layout presentation, and serving method techniques previously found to increase FV purchases (Perry et al., 2004; Wansink, 2004; Just et al., 2008; Mancino & Guthrie, 2009; Bandoni et al., 2011; Wansink, Just, et al., 2010, 2011; Wansink, Smith, et al., 2010, 2011; Thorndike et al., 2012) were associated with lower FV servings and overall consumption in this sample.

Increases in the *variety* subscale were associated with significant increases in the total and side FV percentage consumed as found in prior studies, but not serving outcomes (Adams et al., 2005; Bucher et al., 2011; Just et al., 2012; Kahn & Wansink, 2004). This suggested that variety, as well as choice, may indeed play a role in influencing FV servings and consumption. The variety subscale, which was internally consistent, also contained items gathered from food service staff and not CAFES observations or lunch tray photography. Photographs or labeled sketches of serving stations during CAFES observations could be used in the future to confirm that the variety subscale is a good indicator of actual variety on the day of data collection and CAFES observation.

*Plate scale*. The three internally consistent plate scale items (size, color, and material) were coded from lunch tray photography images. Originally, three subscales were examined during plate scale analysis - size (lunch tray area; number and size of compartments), appearance (shape, material, color), and packaging (whether or not items were in compartments, wrapped or not, or in containers on the tray) - but the subscales suffered from poor internal consistency. The number of lunch tray compartments, contrary to prior work (Kahn & Wansink, 2004), was surprisingly not an internally consistent plate scale item. Packaging of items was not assessed as the range of options was too varied. This remaining three correlated plate scale items (r=0.66), as well as the platykurtic distribution, was likely due to the differences between styrofoam and plastic trays in this sample: styrofoam trays were all the same size and smaller when compared to other trays, the same only offered in white, and all the same material. Other schools used trays of various sizes, colors, and materials, so the plate scale score was more indicative of whether or not meals were “styrofoam tray meals” or not. An item to capture utensil type was also added to CAFES, since utensil availability can affect kids’ ability to consume items such as whole fruits as previously discussed in the *Results* section and prior studies (Lee et al., 2001; Marlette et al., 2005).

An increase in plate scale score was significantly associated with an increase in total FV served, side FV served, total FV consumed, and side FV consumed, consistent with prior studies (Wansink, 1996; Wansink et al., 2005), but a decrease in FV percentage consumed outcomes when entered with other scale scores. These associations occurred because in this sample, the plate scale subscale items primarily indicated whether or not students were served meals on styrofoam trays. Results implied that students who were *not* served meals on a styrofoam tray were served and significantly consumed more total and side FV, but consumed a smaller percentage of the larger servings.

*Food scale*. All food scale items, except for reheat frequency obtained from food service staff, were coded from lunch tray photographs and no in-person observations. Food scale scores, when entered with all other scales, significantly predicted total and side FV percentages consumed. Although the average score of the five food scale items was 52%, it was the least reliable scale and did not meet the internal consistency criterion. The lack of internal consistency was likely due to the exclusion of food quality items. Results of this scale should be cautiously interpreted, considering individual food item packaging and presentation (Sobal & Wansink, 2007) were excluded from CAFES, as well as food quality (e.g., temperature, texture, taste etc.), students' perceptions, and students' food preferences. Children often make food choices based on food scale appearance, in addition to taste and convenience (Neumark-Sztainer et al., 1999). The correlation between the table and food scales was moderately strong because food scale items related to the availability and variety of items on lunch trays, which was somewhat correlated with table scale availability and variety, rather than food item-specific attributes more relevant to the food scale (Sobal & Wansink, 2007).

***Limitations***

Although results indicated that CAFES was generally reliable and valid, the study faced limitations concerning the research design, scope, and potential moderators that must be considered.

*Research design and methods*. CAFES analysis highlighted limitations relating to observations; data collection, scale development, and reliability testing; and the CAFES research design, sample size, and predictive validity analysis. First, observations were most often conducted while students and food were not present in cafeterias. Information gained by observing the interaction between students and their environment during meal times is not captured by CAFES. For example, in one New York school, a fixture for a salad bar was present. We later learned from food service staff that no salad bar was actually available to students because the fixture was too high for students to reach (access). Had the staff person not volunteered this information, CAFES would have assumed that a salad bar was both available and accessible. In other words, just because a CAFES item is present or absent during observation does not mean that the item is actually serving as an affordance (support or barrier) for healthy eating. Furthermore, offering a healthy fruit option may not be enough to increase consumption. Serving peeled and sliced orange pieces rather than whole pieces can increase consumption by making the oranges both available and accessible to young students (Swanson et al., 2009). While CAFES data are useful in quantifying environmental attributes, both quantitative and qualitative data and observations should be used when examining cafeteria environments and behaviors.

Second, not all CAFES items were collected from each school, which interfered with reliability testing. Missing data occurred due to lack of response, the absence of food items during observations and no available staff to answer CAFES item questions, and poor quality or missing photographs. As a result, several schools were eliminated from scale development when more than 50% of CAFES items were missing. Mean item correlations and Kuder-Richardson 21 internal consistency should be calculated with complete data. Furthermore, reliability estimates based on KR-21 coefficients must be cautiously interpreted since KR-21 coefficients are affected by the (large) number of CAFES items, as well as item correlations (Cortina, 1993). CAFES test-retest and inter-rater reliability are also needed to comprehensively assess CAFES reliability. Due to a lack of time and resources, CAFES could not be conducted more than once or by more than one researcher at any school.

Third, the CAFES sample was cross-sectional, small, and suffered from low or no variability among some CAFES items which affected reliability estimates. Predictive validity analysis was also affected by the small sample size. Not enough student level data was collected to account for student level variance, lunch tray photographs were not taken for all students or for three days for all students, and the small number of schools limits the generalizability of the results. Further CAFES validation is needed to assess student level variance and how well CAFES item reliability and validity generalize to other schools.

<u>*Scope*</u>. Although CAFES excluded macroscale factors (e.g., local, state, and federal policies, economics and the cost of food) that influence what schools can prepare for and offer to students, three facets of the microscale cafeteria environment relevant to healthy eating were also beyond the scope of CAFES. First, CAFES considered items relevant to lunch only and *not the entire school day*. Several schools offered USDA breakfast, FV snack, after-school, and weekend backpack snack programs, but participation was not included in CAFES. Participating schools may have more opportunities to increase FV

servings and consumption throughout the school day. Second, *school level policy, pricing, and payment options* were also excluded from CAFES, although all three have been found to affect adults' and high school students' food choices. The cost of food often influences adults' selection more than taste (Glanz, Basil, Maibach, Goldberg, & Snyder, 1998). Offering lower-fat options at reduced prices to adults and high school students encourages purchases of healthier options (*see review*: see French, Jeffery, et al., 2001). Not offering advance menu selection can lead students to make impulsive and unhealthy decisions in the lunch line (Price & Riis, 2012). Third, when students have *choices*, school policies, pricing, and payment options can act as environmental supports and "nudge" students to make healthier decisions (Mancino & Guthrie, 2009). The effectiveness of policies, pricing, and payment options in increasing students' healthy food selection, however, is moderated by whether or not students have a choice. School policy, pricing, and payment option interventions aimed at increasing healthy item selection by students are not relevant in cafeterias where students are handed a meal with no input. Future CAFES data analysis will investigate the presence or absence of choice as a moderator of healthy item selection.

*Potential moderators*. Four potential school- and several student-level moderators of healthy selection and consumption behavior must be noted and warrant further research. First, as previously mentioned, whether or not students have a choice for meal items is critical. The number of choices (i.e., variety), choices for different food types (healthy vs. unhealthy), and the frequency choices are offered matters. When students are given choices, prior research and assessment tools like CAFES can be used to suggest interventions that alter layout, display, and serving methods to increase healthy selection and consumption. However, in schools where all students line up, receive a tray of prepackaged, reheated food and sit down to eat, many validated interventions aimed at "nudging" students to make healthier choices are irrelevant. Although interventions targeting consumption of served foods can still be effective, school policies and macro-level policies and economics beyond the scope of CAFES affect the availability of healthy items on these students' trays.

Second, the amount of time students have for meals can affect their choices and consumption, even when they do not have a choice of meals. For example, if students are given whole fruit that must be cut or peeled, they may be less likely to select and consume that piece because of the added inconvenience, difficulty, and extra time required (Swanson et al., 2009). Furthermore, long lines and crowded spaces, along with time pressures, can lead students to making unhealthy and impulsive selections (Mancino & Guthrie, 2009).

Third, students pay for daily school meals, including free and reduced-price meals, with either cash or prepaid accounts monitored by meal cards that are debited daily in cafeteria checkout lines (Bland, 2004). These payment options can also be used to encourage healthier daily meal choices (Cawley, 2004; Hill, Sallis, & Peters, 2004). Regulating foods available to purchase through prepaid lunch accounts (e.g., "cash for cookies") increased selection and consumption of healthier foods by older students without affecting cafeteria revenue (Wansink, Just, & Payne, 2008). Although this has not been examined among younger elementary school students, offering various payment options could moderate the relationship between FV presentation or placement in the lunch line and students' selection of these items.

Fourth, CAFES excluded influences of the social environment from peers, teachers, and policies. Although few studies have documented influences of school personnel and student peers on students' dietary intake at school, school personnel with proper education and training can serve as role models by establishing and enforcing policies and curricula that support healthy choices (Wechsler, Devereaux, Davis, & Collins, 2000). Teachers, specifically, can affect their students' behaviors through role modeling and social support as described by social learning theory (Bandura, 1986). Although teachers have little control over whether students actually perceive them as role models, the possibility of vicarious learning always exists (Bandura, 1986; Davis, 1999). The nutrition, dieting, and weight control knowledge, values, attitudes, and behaviors of teachers and other school personnel could partially account for the success or failure of healthy eating programs implemented in schools (Yager & O'Dea, 2005).

At the student level, several additional potential moderators of FV servings and consumption were excluded from CAFES. Students' *gender*, *BMI*, *socioeconomic status*, and *ethnicity* were not considered, but have been associated with eating behaviors and obesity (*see reviews*: Rosenkranz & Dzewaltowski, 2008; Tandon et al., 2012; Zhang & Wang, 2004). Students' *hunger level* was also not accounted for, which relates to the time of day lunch is served, and whether lunch occurs before or after recess or physical education classes (Smith, 1980). Additionally, student's *perceptions* of and *preferences* for the food and environment were also not explored. Children often make food choices based on appeal, taste, and convenience (Neumark-Sztainer et al., 1999). CAFES assessed the "attractiveness" of serving area food and some aspects of access and convenience, but children's perceptions of these constructs that affect selection and consumption were not included.

### *Implications*

By identifying environmental attributes associated with healthy eating at multiple scales, CAFES can (1) be used to validly and reliably identify critical areas for intervention and develop low- and no-cost intervention strategies to promote FV consumption; (2) be made available via a web application for use by researchers, food service managers, public health departments, and school personnel in long and short forms; and (3) contribute to guidelines for cafeteria design, food layout, food presentation, and other behavioral economic intervention strategies aimed at increasing FV consumption among elementary school students.

(1) CAFES, validated by consumption and not just purchase data, can be used by researchers and school personnel to identify areas where environmental supports are both

successful and needed, prioritize the focus and scale of interventions, and identify no or low-cost strategies to overcome barriers to healthy eating within school cafeterias. (2) Two versions of the final CAFES instrument will be available online and in hard copy: a "long form" to be used primarily by researchers, and a "short form" to be used by school personnel who require a quick, parsimonious instrument that provides immediate feedback via the four scale scores. After completing the short version of CAFES on site, total and subscale scores can be calculated to determine whether they are low, medium, or high. School personnel will then be directed to a set of recommendations (see #3) indicating how to improve upon a given subscale through low- and no-cost intervention strategies. (3) As a complement to the CAFES short and long forms, a series of recommendation factsheets providing low and no-cost environmental interventions (e.g., how to arrange and present food to encourage healthy choices) will be developed that school staff can immediately implement. The factsheets can be used as a stand-alone resource as well as in conjunction with the CAFES scores. Sheets would not only inform school personnel and researchers, but also designers of school cafeterias.

***Potential Applications***

CAFES can be used before and after elementary school cafeteria interventions intended to encourage healthy eating to assess intervention effectiveness. Comparisons can also be conducted between schools with different approaches to school lunches, as well as to compare how school policies interact with environmental supports to promote or hinder healthy behaviors. For example, if school policies exist to promote the incorporation of fresh local produce into school meals, but preparation equipment and space are lacking, CAFES results will reveal this information to school personnel. CAFES can also be re-administered during post-data collection in the larger USDA-funded study to explore how the environment supported or hindered integration and promotion of school garden produce into the cafeteria.

Additionally, all school districts that are currently enrolled in federal meal programs are required to develop a wellness policy for students that promotes healthy eating and adequate amounts of physical activity.  What the policy must cover is outlined by the Child Nutrition and WIC Reauthorization Act of 2004, but school policy content and how it is implemented is determined by local school districts (Cornell Center for Behavior Economics in Child Nutrition Programs, 2011; U.S. Department of Agriculture, 2004).  Since the arrangement of school cafeterias and foods can affect students' choices, the unintended consequences of the design and layout are important to consider.  Given that school officials and food service staff do influence the types of foods that are served and how they are presented, using the proposed assessment tool to establish interventions as part of the wellness policy may assist in promotion health eating among students.

***Future research***

Future work can improve upon the previously mentioned research design issues. Using a larger, more varied sample to further validate CAFES, including calculating test-retest and inter-rater reliability, would improve the generalizability of CAFES.  Examining moderators may also alter or add additional items to CAFES.  Individual, rather than combined, FV outcomes could also be examined to determine whether interventions aimed at various CAFES items are more effective in increasing servings and consumption of fruits rather than vegetables, and vice versa.  Whether or not certain CAFES items should be weighted can also be explored.

Furthermore, a larger, more varied sample could be used to establish minimum CAFES scores required (e.g., is 75% or 100% necessary) to achieve desired FV outcomes, such as a certain percentage increase in overall FV consumption, or to reduce the number of students not meeting USDA recommendations for daily FV intake.  The USDA's Dietary

Guidelines for Americans recommends that children between the ages of 9 and 13[51], which includes the fourth and fifth graders in this study, consume one-and-a-half to two cups of fruit and two to two-and-a-half cups of vegetables per day (USDA & USDHHS, 2010). Second graders fall under recommendations for children between the ages of 4 - 8 and should consume one-and-a-half cups of fruit and one-and-a-half to two-and-a-half cups of vegetables daily (USDA & USDHHS, 2010). Table 4.16 indicates the number of students in this study (out of the 2506 with lunch tray photography who participated in the USDA lunch program) who were not served, did not select, or consumed *no FV* during all three days of lunch tray photography data collection.

***Table 4.16. CAFES students who were not served, did not select, or consumed zero FV***

| | **0 FV served** | | **0 FV consumed** | | **0% FV consumed** | |
|---|---|---|---|---|---|---|
| | *# students* | *%* | *# students* | *%* | *# students* | *%* |
| ***TOTAL MEAL*** | | | | | | |
| Fruits | 428 | 17% | 676 | 27% | 248 | 10% |
| Vegetables | 463 | 18% | 670 | 27% | 207 | 8% |
| **Total FV** | **134** | **5%** | **237** | **9%** | **103** | **4%** |
| ***SIDE DISH*** | | | | | | |
| Fruits | 481 | 19% | 719 | 29% | 238 | 9% |
| Vegetables | 706 | 28% | 975 | 39% | 269 | 11% |
| **Total FV** | **191** | **8%** | **339** | **14%** | **148** | **6%** |

Although students receiving free and reduced-price meals are typically served and consume more FV (Food and Nutrition Service & Office of Research Nutrition and Analysis, 2007), the 27, 29, 27, and 39 percent of students in Table 4.16 who consumed zero grams of total fruit, side fruits, total vegetables, and side vegetables, respectively, suggest that future work should focus on using CAFES results to increase FV selection and consumption among these students. Table 4.16 also indicates that only four to six percent of students ate none

[51] USDA FV daily consumption recommendations (Beth et al., 2008):
-Ages 4-8 years: 1.5 cups of fruit/day; 1.5–2.5 cups of vegetables/day.
-Ages 9-13 years: 2–2.5 cups vegetables/day.
-Boys: 1.5-2 cups of fruit/day; Girls: 1.5 cups of fruit/day.

of the FV that they were served or that they selected, which emphasizes the importance of increasing students' servings and selection of FV.

Future work could also explore adding additional items to CAFES that were excluded from this study to make it more comprehensive. For example, since Table 4.16 highlighted the need to increase FV servings, the addition of kitchen, preparation, and serving area inventory items could explore associations between available equipment, space, and staff to healthy item availability, presentation, and students' FV serving outcomes. Furthermore, CAFES offers an instrument for systematic environmental observation related to physical elementary school cafeteria environments and healthy eating that can be updated as future research is completed. Additional CAFES items can be added based on new research and validated, promising environmental interventions. For example, an item could be added that captures whether schools use images of FV in lunch tray compartments to encourage selection of FV. One study found that photographs of green beans and carrots placed in lunch tray compartments were associated with increases in vegetable selection and consumption among kindergarten to 5$^{th}$ grade elementary school students (75% racial/ethnic minorities; 72% eligible for FRPM) when compared to trays with no photographs (Reicks, Redden, Mann, Mykerezi, & Vickers, 2012). Results from this study suggest another low-cost intervention strategy, since installing photographs required no training, $3, and 20 minutes per 100 trays. Although data were only collected over two days and the longitudinal effects were not assessed, future research on interventions similar to this one may generate additional items to add to CAFES.

Finally, future data collection using CAFES could explore whether or not CAFES items are valid and reliable with more varied samples, settings, and locations. Cultural differences were also not considered in CAFES development. Comparing results from schools in the U.S. to other countries could also reveal additional intervention strategies, or the need for alternate versions of CAFES in different settings and contexts.

### ***Conclusion***

School cafeterias can attract students and encourage healthy eating by becoming efficient and attractive spaces, promoting nutrition and physical education, and nudging students to make healthier choices through interventions at various scales (Gorman et al., 2007; Just et al., 2007; Just et al., 2008; Mancino & Guthrie, 2009). Some schools have hired culinary experts to develop appealing, healthy meals and transform cafeterias into welcoming, attractive spaces with natural lighting, artwork, and reduced noise to increase student participation in school meal programs (Gorman et al., 2007; Story et al., 2006). CAFES, however, offers a valid, reliable, and practical instrument school staff can use to identify specific items to improve that have been empirically linked to increasing healthy FV selection and consumption. Results allow school staff to leverage low- or no-cost strategies, which is especially critical when facing financial constraints. CAFES was one of the first attempts to develop a comprehensive, observer-based environmental assessment instrument related to diet in elementary school cafeterias. Study results showed that CAFES is generally reliable and practical to use by both researchers and Extension Educators with little training, but using an online version and automatic generation of scores must still be explored. The CAFES scales and subscale scores, when accompanied with low- and no-cost intervention suggestion documentation to be developed in the future, should be useful in guiding school staff, researchers, nutritionists, designers, and public health policy makers in creating cafeteria environments that facilitate healthy eating.

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CHAPTER 5

# CONCLUSION

## SUMMARY

The three previously described dissertation studies explored influences of the built and natural environment on human mental and physical health. Each study focused on understudied environmental influences within one of children's three most proximate settings: home, neighborhood, and school. Chapter 2 examined whether residential design attributes moderated the crowding-psychological health and crowding-physiological stress relations among children. Chapter 3 developed a procedure to quantify amounts of nature, considering the well-documented benefits of nature exposure to mental and physical health. Chapter 4 developed the first objective, reliable, and valid instrument to assess attributes of elementary school cafeteria environments associated with students' fruit and vegetable intake. Together, the three-paper series generally supported the notion that the built and natural environment affect health and health behaviors, and that standardized, validated instruments are needed to assess these influences. Studies further focused on low-income children – who are likely to face multiple environmental and psychological stressors (Evans & English, 2002; Gillis, 1979; Saegert, 1982) – and aimed to generate evidence that would inform interventions and policies focusing on vulnerable children's health and their most proximate settings.

### ***Chapter 2: Potential design moderators of the residential crowding – psychological health and crowding – physiological stress relations among children***.

Chapter 2 aimed to: 1) examine the relation between residential interior density and children's self-reported crowding and 2) investigate the potential of design attributes to buffer the adverse effects of crowding on children's psychological health and physiological stress. Interior density significantly predicted home and bedroom crowding when controlling for income-to-needs and gender, but interior density and crowding were only modestly correlated. Aim 2 findings suggested that, when controlling for income-to-needs, children's bedroom ceiling height primarily buffered the negative effects of home and target child bedroom (TCB) crowding on psychological health and physiological stress outcomes. Results indicated that residential design attributes significantly moderated the two relations between *crowding*, not interior density, and psychological health and physiological stress. This suggests that future research might explore and residential environmental interventions focus on not only reducing interior density, but also on children's perceptions of interior density.

Despite several research design limitations and the need for additional research, this study was one of few to examine the potential of design attributes to moderate the crowding-psychological health and crowding-physiological stress relations. Moreover, standardized indices of children's psychological health and physiological stress - based on observations, parent reports, and children's self-reports - were used. Additionally, few studies have tested the predictive validity of depth and permeability, two space syntax theoretical constructs. Finally, results extended prior work (Savinar, 1975) on crowding and ceiling height among adults to children. Findings also confirmed that children living in crowded homes who can retreat to a space of their own suffer fewer negative effects of crowding (Wachs & Gruen, 1982), and revealed that the design of that space may also play a role.

***Chapter 3: Objectively quantifying nearby nature: Land cover data and automated GIS procedures vs. manually-rated satellite images***

While Chapter 2 incorporated existing measures of residential environments derived from space syntax theory, Chapter 3 addressed the need for a simplified, accessible, standardized procedure to measure a physical environmental attribute: quantity of nearby nature. A substantial body of literature has demonstrated the benefits of nature exposure on various facets of human physical and mental health (*see review*: Wells & Rollings, 2012); however, the question of "dose" (e.g., Barton & Pretty, 2010) of nature required to obtain these benefits remains largely elusive. This uncertainty is partially attributed to the lack of a common, accessible nature estimation method. The Chapter 3 study developed and tested a nature estimation method using freely available Google Earth satellite images. The Google Earth method addressed limitations of National Land Cover Database data and automated Geographic Information Systems procedures often used to estimate amounts of nature. Comparisons between methods revealed that the Google Earth method was more appropriate for estimating nearby nature in dense, highly developed urban areas, while either method could be used to estimate nearby nature within locations of varying urbanity. The freely available Google Earth method that requires no GIS experience contributes to the development of a common measure for use in future studies on nature and health.

***Chapter 4: Cafeteria assessment for elementary schools (CAFES): Instrument development***

Chapter 4 assessed environmental influences on children's physical health related to childhood obesity. Considering the amount of time children spend in school and that federally-funded breakfast and lunch programs feed millions of students daily, school cafeterias have great potential to encourage healthy eating. The CAFES study developed and tested a valid, reliable, and objective tool to quantify a broad range of environmental attributes, based on prior environmental psychology and behavioral economics work, linked to selection and consumption of fruits and vegetables (FV).

CAFES is the first assessment instrument focused on the physical elementary school cafeteria environment as it relates to healthy eating. The study contributes to the development of a methodology to evaluate existing school cafeterias, and future standardized guidelines that promote healthy and discourage unhealthy eating. Despite sample size and missing data limitations, CAFES proved to be a fairly reliable, practical, and inexpensive assessment tool. By focusing explicitly on elementary schools, NSLP participants, and FRPM recipients, CAFES scores highlight specific areas on which to focus low- and no-cost intervention strategies that can immediately be implemented to especially benefit high risk and underserved FRPM student populations.

### ***Collective strengths***

Collectively, the three dissertation studies contributed to the literature in two significant ways. First, the crowding (Chapter 2) and CAFES (Chapter 4) studies provided promising evidence that the physical environment matters within the context of mental and physical health. Policy makers, planners, architects, and designers are especially faced with a paucity of evidence-based design guidelines relating to environments and health. Design attributes of crowded, high interior density housing can potentially buffer adverse effects on children (Chapter 2), while elementary school cafeteria design can support students' healthy and hinder unhealthy food selection and consumption (FV, Chapter 4). The Google Earth nature estimation method (Chapter 3) can be used to determine required square footage of urban park area or the square footage of natural window views needed to benefit residents' health. CAFES results (Chapter 4) can also be used to not only identify low- and no-cost intervention strategies school staff can immediately implement to increase children's selection and consumption of FV, but also contribute to cafeteria design guidelines.

Second, two reliable and freely accessible environmental assessment tools were developed. Google Earth nature estimation procedures (Chapter 3) can assist in studies to establish the amount of nature needed to achieve the well documented benefits to health, while CAFES (Chapter 4) can enable researchers and school staff to identify environmental intervention strategies aimed at increasing elementary school students' diet and physical activity. Furthermore, examining the predictive validity of space syntax constructs – depth and permeability – indicated that those often overlooked measures may be relevant to children's perceptions of high residential interior density.

### ***Collective limitations***

Despite the strengths of the three studies, three general limitations must be noted. Methodologically, all studies were cross-sectional, focused primarily on low income children (Chapters 2 and 4), included relatively small sample sizes, and excluded several potential moderators. Future longitudinal studies of larger, representative samples are necessary to improve the generalizability of results. Additionally, recognizing moderating factors, such as culture, socioeconomic status, urbanity, gender, age, and location, of the physical environment-health relation is critical. Future research including these factors is needed to determine whether study findings extend to different populations and settings.

Second, all studies focused on quantitative and mostly observational, objective data. Subjective, qualitative data, however, must also be considered when examining the relation between the physical environment and health. The presence of environmental attributes or affordances associated with health, alone, may not be enough to improve health or encourage healthy behaviors (Gibson, 1977). The discussion in Chapter 3 concerning quantity versus quality of natural areas can be extended to homes, neighborhoods, and schools. In addition to personal preferences, subjective perceptions of housing quality, school cafeteria aesthetics, and neighborhood attractiveness, for example, may moderate and even mediate the relationship between the physical environment and health (Alfonzo, 2005). The combination of qualitative and quantitative data can inform our understanding of physical environmental influences on mental and physical health.

Third, all studies focused on influences of the physical environment and individuals' health within microsystems (Bronfenbrenner, 1979). Each scalar level of the environment, however, is a complex system nested within other levels that all contain physical, social, and individual components. To address the interactive nature of health and the environment, factors and interactions across all levels must be considered (Bronfenbrenner, 1979; Stokols, 1992). Physical and social factors within the environment directly and indirectly affect health; people also influence the health-promotive qualities of the environment through individual and collective behaviors (Stokols, 1992). Therefore, strategies to create, evaluate, and maintain health-promotive children's environments must address not only influences within immediate environments (e.g., students in schools), but also more distant influences (e.g., school boards and educational policies).

### ***Collective implications and future research directions***

Results from the collection of three dissertation studies have implications for policy, practice, and design. Design professions, including architecture and planning, have the potential to contribute to the creation and maintenance of healthy and health-promotive environments (Stokols, 1992). Increasing complexities of architectural practice and construction technology have contributed to a profession often overly consumed by building composition and aesthetics; material selection; satisfying code requirements; overcoming site constraints; reconciling conflicting needs of users, clients, and the public; and limited funding (Hadjiyanni, 2008; Moore, 1979). The impacts of buildings and spaces on human behavior, health, and well-being are often overlooked (Stokols, 1992). The two freely available instruments developed as part of this dissertation provide design practitioners, in addition to researchers, policy makers, and other professionals, with practical tools that identify environmental attributes related to design and health. Empirical evidence generated from these standardized instruments also informs designers and policy makers working with residential and educational environments. This evidence can guide renovations of existing and inform plans for future housing developments and schools.

Future research can expand upon findings from the three dissertation studies, as well as examine how to best disseminate and translate evidence to practitioners and policy makers. Longitudinal studies with representative samples would establish whether findings apply to multiple populations and settings, as well as *when* attributes of the physical environment influence health outcomes and behaviors the most. Future studies using rigorous methodologies and multilevel analyses will provide compelling evidence that the physical environment and its design matters to human health.

Once rigorous empirical evidence exists, it must be disseminated and translated into forms accessible to and understood by practitioners and policy makers. Empirical evidence and environmental assessment instruments are often only available via subscription to academic journals and formatted for other researchers rather than practitioners and policy makers. Future collaboration between researchers, practitioners, and policy makers could explore best practices for translating evidence into applicable forms such as design guidelines; dissemination, including open access journals; and identifying additional studies needed, such as evaluating cost effectiveness of suggested evidence-based strategies.

Additionally, future environments and health research may benefit from converging efforts to promote health and sustainability (Huang, 2009). According to the Swedish government, good health has become an important resource for sustainable development (Stigsdotter, 2005). Until recently, efforts examining sustainability and the built environment primarily focused on building construction and energy efficiency. Requirements for sustainable construction are beginning to make connections between sustainability and health. In the U.S., for example, Leadership in Energy and Environmental Design (LEED) sustainable design and construction requirements now include an ergonomic component. Furthermore, green building methods are frequently associated with "cleaner" and healthier environmental qualities. LEED certified buildings are required to use "green" materials and cleaning products, reducing exposure to poor indoor environmental air quality and chemical toxins. Incorporating health into sustainable design requirements, as well as combining research efforts in health and sustainability, may be a more effective approach to generating and applying empirical evidence in practice. Combined efforts to address the complex issues surrounding health and sustainability may also be more successful in generating public and political support for large-scale solutions and interventions (Zeisel, 2006). Until then, inter- and multidisciplinary collaboration is needed among researchers, policy makers, public health officials, epidemiologists, pediatric health care providers, behavioral psychologists, nutritionists, urban planners, landscape architects, parks and transportation departments, food stores, physical activity facilities and programs, schools, community boards, community organizations, and neighborhood residents to further our understanding of environmental influences on mental and physical health, and to generate the most effective environmental intervention strategies.

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# APPENDIX A

***Table A.1. Interaction between <u>house</u> interior density and design attributes on psychological health and physiological stress, controlling for income-to-needs***

| **Predictor**[a] | Psych. distress | Social withdrawal | Learned helplessness | Rutter | Harter | Resting systolic blood pressure | Resting diastolic blood pressure | Norepinephrine[b] | Epinephrine[b] | Cortisol[b] | Allostatic load[c] (upper quartile) | Allostatic load[c] (median) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interior density (home) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Home depth | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | -- | -- | * | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | |
| Interior density (home) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| TCB Depth | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | -- | -- | * | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | |
| Interior density (home) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Home permeability | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | -- | -- | * | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | |
| Interior density (home) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| TCB window area | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | * | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | |
| Interior density (home) | -- | -- | -- | -- | -- | -- | ** | -- | -- | -- | -- | -- |
| TCB ceiling height (low) | -- | -- | -- | -- | -- | ** | ** | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | -- | -- | ** | ** | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | |
| Interior density (home) | -- | -- | -- | -- | -- | -- | ** | -- | -- | -- | -- | -- |
| TCB volume | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | -- | -- | -- | * | * | -- | -- | -- | -- |

a = All models controlled for income-to-needs ratio
b = log, with creatine covariate
c = interpolated

-- = not significant ($p$>0.10)
* = marginally significant ($p$<0.10)
** = significant ($p$<0.05)

## APPENDIX A (*continued*)

***Table A.2. Interaction between TCB interior density and design attributes on psychological health and physiological stress, controlling for income-to-needs***

| **Predictor**[a] | Psych. distress | Social withdrawal | Learned helplessness | Rutter | Harter | Resting systolic blood pressure | Resting diastolic blood pressure | Norepinephrine[b] | Epinephrine[b] | Cortisol[b] | Allostatic load[c] (upper quartile) | Allostatic load[c] (median) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interior density (TCB) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| TCB window area | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | ** | -- | -- | -- | -- | ** | -- | -- | -- |
| | | | | | | | | | | | | |
| Interior density (TCB) | -- | -- | -- | -- | -- | -- | ** | -- | -- | -- | -- | -- |
| TCB ceiling height (low) | -- | -- | -- | -- | -- | -- | ** | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | -- | -- | ** | ** | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | |
| Interior density (TCB) | -- | -- | -- | -- | -- | ** | -- | -- | -- | -- | -- | -- |
| TCB Volume | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Interaction** | -- | -- | -- | -- | -- | * | -- | * | -- | -- | -- | -- |

a = All models controlled for income-to-needs ratio
b = log, with creatine covariate
c = interpolated

**--** = not significant ($p$>0.10)
* = marginally significant ($p$<0.10)
** = significant ($p$<0.05)

***No significant results were found for home depth, TCB depth, or home permeability.***

# APPENDIX B

***Table B.1. Literature review: Variations in objective measures of nature***

| Nature exposure | Citations *(s. = study #)* | Independent variables: Nature definition and/or measurement | Dependent variables |
|---|---|---|---|
| **Images, videos** | Berman et al., 2008 (s.2)<br>Berto, 2005 (s.1, 3)<br>Diette et al., 2003<br>Felsten, 2009<br>Herzog et al., 1997<br>Pretty et al., 2005<br>Sullivan et al., 2004<br>Faber Taylor et al., 2001 (s.1, 2)<br>Ulrich et al., 1991 | **Natural images**: Novia Scotia scenery; lakes, rivers, seas, hills, woods, orchards, forests; mountain spring meadow mural; leafless trees in late fall with minimal built structures, fields and forests of trees with colorful leaves, seacoast or waterfall; natural, sports entertainment; rural pleasant, rural unpleasant; flowers, trees, animals; tree cover, grass in yard; natural vegetation, water; grass, trees/tree canopy (5 point scale)<br><br>**Urban images**: Ann Arbor, Detroit and Chicago; city streets, industrial zones, housing, porches, urban areas, skyscrapers; all built structures; urban; urban pleasant, urban unpleasant; human built, non-green outdoor space; urban light/heavy traffic, urban with few/many pedestrians; no trees or grass (5 point scale) | Directed-attention abilities, attentional capacity, attentional functioning, perceived restorativeness, perceived restorative effectiveness, physical (blood pressure) and mental health (self-esteem and mood), patient-reported pain and anxiety, stress recovery, Vitality of space, use of space, amount of social activity, proportion of social/nonsocial activities |
| **Epidemiological** | de Vries et al., 2003<br>Groenewegen et al., 2006 (s.1)<br>Maas et al., 2006<br>Maas, De Vries, et al., 2009<br>Maas, van Dillen, et al., 2009<br>Takano et al., 2002<br>Mitchell et al., 2008 | **Proximity/nearby:** Nearby greenery-filled (plants, tree-lined streets, garden) spaces and existence of a nearby garden<br><br>**Percentage of green space:** Urban green, agricultural green, forests and natural areas, peat grassland within 1 and 3km radius from the National Land Cover Classification Database (25mx25m grid, Netherlands); green space within Lower Level Super Output Areas (average physical area=4km) from the Generalised Land Use Database (England); green areas around one's house<br><br>**Percentage of blue space:** Fresh and salt water surfaces within 1 and 3km radius from the National Land Cover Classification Database (25mx25m grid, Netherlands)<br><br>**Urbanity** (housing density-5 point scale), **presence** of a nearby garden | Perceived mental, physical, and general health, morbidity, health via social contacts, longevity |
| **View** | Kaplan, 1988<br>Kaplan, 1993<br>Faber Taylor et al., 2002<br>Tennessen et al., 1995<br>Ulrich, 1984<br>Wells, 2000 | **Natural**: Trees, bushes, grass, flowers; trees, plants, water (5 point scale); all natural, mostly natural (4 point scale: 1= all natural, 4=all built); small stand of deciduous trees<br><br>**Built/man-made**: Street, parking lot, buildings; buildings, street, pavement (5-point scale); mostly built, all built (4 point scale: 1= all natural, 4=all built); brown brick wall<br><br>**Both**: Living room + kitchen view, presence of indoor plants, material of yard (4 point scale: 0=none, 1 = no natural, 2=less than half natural, 3= more than half natural) | Health, psych. functioning, psych. distress, self-worth, life satisfaction, job satisfaction, self-discipline (concentration, delay of gratification, impulse inhibition), capacity to direct attention, mood, restorative effect (# hospitalization days, #/strength of daily analgesics, #/strength of medication doses for anxiety, minor complications, nurses' notes on condition/course of recovery) |

| **Nature exposure** | **Citations** *(s. = study #)* | **Independent variables: Nature definition and/or measurement** | **Dependent variables** |
|---|---|---|---|
| **Direct** | Berman et al., 2008 (s.1)<br>Bixler et al., 2002 (s.1)<br>Bodin et al., 2003<br>Coley et al., 1997<br>Kaplan, 1974<br>Faber Taylor et al., 2008 | **Natural: walk** in arboretum; **play** in woods, fields, lakes; park; # of/distance to trees, vegetation; outdoor cooking, rock climbing; urban park<br>**Natural/not natural:** Residential area<br>**Not natural:** walk in downtown Ann Arbor, MI; urban; downtown area | Directed-attention abilities, environmental preference and perception, emotion, use of outdoor space, self-esteem, confidence, attitude, skill, concentration |
| **View vs. Direct** | Hartig et al., 2003 | Natural **view**: room with view of trees, vegetated hillside and bird/stream sounds<br>Natural **walk**: dirt road, closed to public, with fields and oak-sycamore woodland<br>Urban **view**: room with no view<br>Urban **walk**: medium-density professional office and retail development area | Psychophysiological stress recovery (blood pressure), emotion, attention |
| **Open space** | Giles-Corti et al., 2005<br>Groenewegen et al., 2006 (s.2, 3)<br>Sugiyama, 2009<br>Nielsen et al., 2007 | **Distance to/accessibility of public/neighborhood open space**: local parks, play areas, and village greens; parks, forests, beaches, green sports facilities, green residential areas; green areas | Perceived general health, health, disabilities, acute complaints, chronic illness, obesity, physical/outdoor activity, mental health, well-being, stress life satisfaction |

# APPENDIX C

### *Table C.1a. Predictive validity: Fully unconditional model for CAFES total*

| **SFV CONSUMED**[a] | | Final estimation of fixed effects[a] | | | | |
|---|---|---|---|---|---|---|
| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
| Mean %SFV consumed, $\gamma_{00}$ | 29 | 0.644 | 0.026 | 24.52 | 28 | **<0.001** |
| | | **Final estimation of variance components** | | | | |
| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
| Level 2 $\mu_{0j}$ | | 0.018 | 0.135 | 318.26 | 28 | **<0.001** |
| Level 1 $r_{ij}$ | 1544 | 0.096 | 0.310 | | | |

***a****= with robust standard errors*
***b****= student level 1 and school level 2 sample sizes*
***c=  Bolded p-value** indicates significance at the 0.05 alpha level*

### *Table C.1b. Predictive validity: Partially conditional model for CAFES total*

| **SFV CONSUMED**[a] | | Final estimation of fixed effects[a] | | | | |
|---|---|---|---|---|---|---|
| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
| Mean %SFV consumed, $\gamma_{00}$ | 29 | 0.644 | 0.025 | 25.91 | 26 | **<0.001** |
| $\gamma_{01}$ % FRPM | | -0.190 | 0.194 | -0.98 | 26 | 0.335 |
| $\gamma_{02}$ % Minority | | -0.051 | 0.094 | -0.55 | 26 | 0.590 |
| | | **Final estimation of variance components** | | | | |
| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
| Level 2 $\mu_{0j}$ | | 0.017 | 0.132 | 280.18 | 26 | **<0.001** |
| Level 1 $r_{ij}$ | 1441 | 0.096 | 0.310 | | | |

***a*** *= with robust standard errors*
***b*** *= student level 1 and school level 2 sample sizes*
***c =  Bolded p-value** indicates significance at the 0.05 alpha level*

# APPENDIX D

## *Tables D.1a-f. Predictive validity: Fully unconditional models for CAFES scales*

**a. FV SERVED**[a]

**Final estimation of fixed effects** *(with robust standard errors)*

| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Mean FV served, $\gamma_{00}$ | 16 | 185.89 | 16.39 | 11.34 | 15 | **<0.001** |

**Final estimation of variance components**

| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | | 4409.76 | 66.41 | 542.68 | 15 | **<0.001** |
| Level 1 $r_{ij}$ | 1069 | 9726.00 | 98.62 | | | |

**b. FV CONSUMED**[a]

**Final estimation of fixed effects** *(with robust standard errors)*

| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Mean FV consumed, $\gamma_{00}$ | 16 | 110.30 | 11.27 | 9.79 | 15 | **<0.001** |

**Final estimation of variance components**

| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | | 2021.49 | 44.96 | 283.63 | 15 | **<0.001** |
| Level 1 $r_{ij}$ | 1069 | 8085.36 | 89.92 | | | |

**c. FV % CONSUMED**[a]

**Final estimation of fixed effects** *(with robust standard errors)*

| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Mean % FV consumed, $\gamma_{00}$ | 16 | 0.600 | 0.037 | 16.38 | 15 | **<0.001** |

**Final estimation of variance components**

| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | | 0.021 | 0.146 | 279.33 | 15 | **<0.001** |
| Level 1 $r_{ij}$ | 1041 | 0.080 | 0.283 | | | |

**d. SFV SERVED**[a]

**Final estimation of fixed effects** *(with robust standard errors)*

| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Mean SFV served, $\gamma_{00}$ | 16 | 166.32 | 15.92 | 10.45 | 15 | **<0.001** |

**Final estimation of variance components**

| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | | 4173.35 | 64.60 | 556.39 | 15 | **<0.001** |
| Level 1 $r_{ij}$ | 1069 | 8290.81 | 91.05 | | | |

**e. SFV CONSUMED**[a]

**Final estimation of fixed effects** *(with robust standard errors)*

| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Mean SFV consumed, $\gamma_{00}$ | 16 | 97.91 | 10.98 | 8.92 | 15 | **<0.001** |

**Final estimation of variance components**

| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | | 1929.70 | 43.93 | 287.07 | 15 | **<0.001** |
| Level 1 $r_{ij}$ | 1069 | 7144.64 | 84.53 | | | |

**f. SFV % CONSUMED**[a]

**Final estimation of fixed effects** *(with robust standard errors)*

| **Fixed Effect** | $n^b$ | *Coefficient* | *SE* | *t-ratio* | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Mean %SFV consumed, $\gamma_{00}$ | 16 | 0.598 | 0.037 | 16.11 | 15 | **<0.001** |

**Final estimation of variance components**

| **Random Effect** | | *Variance component* | *SD* | $X^2$ | *d.f.* | *p-value*[c] |
|---|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | | 0.022 | 0.148 | 258.84 | 15 | **<0.001** |
| Level 1 $r_{ij}$ | 1011 | 0.091 | 0.301 | | | |

***a****= with robust standard errors* ***b****= student level 1 and school level 2 sample sizes* ***c= Bolded p-value*** *indicates significance at the 0.05 alpha level*

# APPENDIX E

## *Tables E.1a-f. Predictive validity: Partially conditional models for CAFES scales*

**a. FV SERVED[a]** — **Final estimation of fixed effects[a]**

| Level | Fixed Effect | n[b] | Coefficient | SE | t-ratio | d.f. | p-value[c] |
|---|---|---|---|---|---|---|---|
| For Intercept, $\beta_0$ | $\gamma_{00}$ Intercept | *1069* | 185.73 | 15.29 | 12.15 | 13 | **<0.001** |
| | $\gamma_{01}$ % FRPM | | *136.12* | 96.19 | 1.42 | 13 | 0.181 |
| | $\gamma_{02}$ % Minority | | -64.69 | 69.22 | -0.94 | 13 | 0.367 |
| For Grade, $\beta_1$ | $\gamma_{10}$ Intercept | *16* | 5.72 | 20.76 | 0.28 | 1052 | 0.783 |

**Final estimation of variance components**

| Random Effect | Variance component | SD | $X^2$ | d.f. | p-value[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 4527.43 | 67.29 | 506.87 | 13 | **<0.001** |
| Level 1 $r_{ij}$ | 9728.89 | 98.64 | | | |

**d. SFV SERVED[a]** — **Final estimation of fixed effects**

| Fixed Effect | n[b] | Coefficient | SE | t-ratio | d.f. | p-value[c] |
|---|---|---|---|---|---|---|
| $\gamma_{00}$ Intercept | *16* | 97.84 | 10.81 | 9.05 | 13 | **<0.001** |
| $\gamma_{01}$ % FRPM | | *12.55* | 65.37 | 0.19 | 13 | 0.851 |
| $\gamma_{02}$ % Minority | | -27.60 | 32.77 | -0.84 | 13 | 0.415 |
| $\gamma_{10}$ Intercept | *1069* | 11.17 | 11.68 | 0.96 | 1052 | 0.339 |

**Final estimation of variance components**

| Random Effect | Variance component | SD | $X^2$ | d.f. | p-value[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 2150.25 | 46.37 | 277.29 | 13 | **<0.001** |
| Level 1 $r_{ij}$ | 7128.36 | 84.43 | | | |

**b. FV CONSUMED[a]** — **Final estimation of fixed effects[a]**

| Level | Fixed Effect | n[b] | Coefficient | SE | t-ratio | d.f. | p-value[c] |
|---|---|---|---|---|---|---|---|
| For Intercept, $\beta_0$ | $\gamma_{00}$ Intercept | *16* | 110.20 | 10.97 | 10.04 | 13 | **<0.001** |
| | $\gamma_{01}$ % FRPM | | -28.48 | 67.21 | -0.42 | 13 | 0.679 |
| | $\gamma_{02}$ % Minority | | -25.03 | 38.34 | -0.65 | 13 | 0.525 |
| For Grade, $\beta_1$ | $\gamma_{10}$ Intercept | *1069* | 10.07 | 15.27 | 0.66 | 1052 | 0.510 |

**Final estimation of variance components**

| Random Effect | Variance component | SD | $X^2$ | d.f. | p-value[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 2211.70 | 47.03 | 262.36 | 13 | **<0.001** |
| Level 1 $r_{ij}$ | 8074.30 | 89.86 | | | |

**e. SFV CONSUMED[a]** — **Final estimation of fixed effects**

| Fixed Effect | n[b] | Coefficient | SE | t-ratio | d.f. | p-value[c] |
|---|---|---|---|---|---|---|
| $\gamma_{00}$ Intercept | *16* | 97.84 | 10.81 | 9.05 | 13 | **<0.001** |
| $\gamma_{01}$ % FRPM | | 12.55 | 65.37 | 0.19 | 13 | 0.851 |
| $\gamma_{02}$ % Minority | | -27.60 | 32.77 | -0.84 | 13 | 0.415 |
| $\gamma_{10}$ Intercept | *1069* | 11.17 | 11.68 | 0.96 | 1052 | 0.339 |

**Final estimation of variance components**

| Random Effect | Variance component | SD | $X^2$ | d.f. | p-value[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 2150.25 | 46.37 | 277.29 | 13 | **<0.001** |
| Level 1 $r_{ij}$ | 7128.36 | 84.43 | | | |

**c. FV % CONSUMED[a]** — **Final estimation of fixed effects[a]**

| Level | Fixed Effect | n[b] | Coefficient | SE | t-ratio | d.f. | p-value[c] |
|---|---|---|---|---|---|---|---|
| For Intercept, $\beta_0$ | $\gamma_{00}$ Intercept | *16* | 0.600 | 0.030 | 19.99 | 13 | <0.001 |
| | **$\gamma_{01}$ % FRPM** | | **-0.515** | **0.212** | **-2.43** | **13** | **0.030** |
| | $\gamma_{02}$ % Minority | | -0.051 | 0.108 | -0.466 | 13 | 0.649 |
| For Grade, $\beta_1$ | $\gamma_{10}$ Intercept | *1042* | 0.019 | 0.031 | 0.597 | 1052 | 0.551 |

**Final estimation of variance components**

| Random Effect | Variance component | SD | $X^2$ | d.f. | p-value[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 0.016 | 0.126 | 173.25 | 13 | **<0.001** |
| Level 1 $r_{ij}$ | 0.080 | 0.283 | | | |

**f. SFV % CONSUMED[a]** — **Final estimation of fixed effects**

| Fixed Effect | n[b] | Coefficient | SE | t-ratio | d.f. | p-value[c] |
|---|---|---|---|---|---|---|
| $\gamma_{00}$ Intercept | *16* | 0.598 | 0.031 | 19.33 | 13 | **<0.001** |
| **$\gamma_{01}$ % FRPM** | | **-0.522** | **0.221** | **-2.37** | **13** | **0.034** |
| $\gamma_{02}$ % Minority | | -0.030 | 0.111 | -0.27 | 13 | 0.791 |
| $\gamma_{10}$ Intercept | *1011* | 0.030 | 0.031 | 0.95 | 1052 | 0.345 |

**Final estimation of variance components**

| Random Effect | Variance component | SD | $X^2$ | d.f. | p-value[c] |
|---|---|---|---|---|---|
| Level 2 $\mu_{0j}$ | 0.017 | 0.130 | 170.16 | 13 | **<0.001** |
| Level 1 $r_{ij}$ | 0.091 | 0.301 | | | |

***a**= with robust standard errors* ***b**= student level 1 and school level 2 sample sizes* ***c**= **Bolded p-value** indicates significance at the 0.05 alpha level*

**APPENDIX F**: CAFES instrument

*Gray text = coding information*

## CAFETERIA ASSESSMENT FOR ELEMENTARY SCHOOLS (CAFES) – LONG VERSION

**Observer name:** ______________________ **State** ______ **School ID#**____________

**SCHOOL NAME:** ____________________________________________

**PARTICIPATING GRADES:** ______ ______________________________

**INSTRUCTIONS: Complete p. 1-11 as noted. Items without one of the following symbols can be completed at any time.**
**☺ = when possible, complete item *just before/during* a meal time ✖ = DO NOT complete item during a meal time**

**SUPPLY LIST:** ☐ *CAFES forms* ☐ *Camera (batteries/memory cards)* ☐ *Ruler & tape measure*
☐ *Pens/pencils & extra blank paper for notes* ☐ *Calculator for coding*

*A (*) throughout CAFES indicates an item that should NOT be included in the total CAFES item count if selected/checked*

| | *1. Please ask Food Service staff and/or Principal the following questions:* | Yes | No | Additional response |
|---|---|---|---|---|
| a. | Are vending machines available for student use during lunch? | ☐ 0 | ☐ 1 | # Machines: |
| b.* | *If yes, are fruits and vegetables available? If a.=no, check N/A.* | ☐ 1 | ☐ 0 | ☐ N/A (*) |
| c. | Do fundraisers involving food occur during lunch time? | ☐ 0 | ☐ 1 | |
| d. | Do fundraisers involving food occur in the cafeteria or eating area(s) during lunch time? | ☐ 0 | ☐ 1 | |
| e.* | Are different portion sizes available for students of different ages/grades (K–3rd / 4th-6th / 7th+)? | ☐ 1 | ☐ 0 | ☐ N/A (*) |
| f. | Are school lunches prepared by a contracted/outside food company? | ☐ | ☐ | |
| g. | What is the total student population? | # students: | | |
| h. | How many students eat per meal period? | # students: | | |
| i. | How many lunch periods occur per day? | # meal periods: | | |

**How many cafeteria/eating areas are used?** ________ **Which grades use each space?** ____________________
*If >1, evaluate the space used by grades of interest, the "main" space, or all spaces with separate forms.*

**2. Are meals prepared (not just reheated) at the school?** ☐ Yes (1) ☐ No (0)

**3. In the last year, which of the following factors <u>helped</u> your school's cafeteria to provide healthier food choices? Check all that apply** (For each item: 0=<u>un</u>checked, 1=checked).

a. ☐ Suitable equipment available b. ☐ More storage space available

**4. In the last year, which of the following factors <u>limited</u> your school's cafeteria to provide healthier food choices? Check all that apply** (For each item: 0=checked, 1=<u>un</u>checked).

a. ☐ Lack of preparation area b. ☐ Lack of display space c. ☐ Lack of storage space

**5. Students serve themselves for (check all that apply):**

a. ☐ A la carte lunch entrees (0=check, 1=<u>un</u>check) b. ☐ A la carte lunch sides (0=check, 1=<u>un</u>check) c. ☐ Salad/fruit (0=<u>un</u>check, 1=check) d. ☐ None (0=check, 1=<u>un</u>check)

**6. Do you use the offer-versus-serve option during lunch (check all that apply)?**

a. ☐ A la carte lunch entrees (0=check, 1=<u>un</u>check) b. ☐ A la carte lunch sides (0=check, 1=<u>un</u>check) c. ☐ Salad/fruit (0=<u>un</u>check, 1=check) d. ☐ None (0=check, 1=<u>un</u>check)

**Observer name:** ______________________________ **State** ________ **School ID#**________________

**7. In an average week, how many times are the following options offered?** Circle all that apply *(e.g., if =3, circle 1, 2, & 3).*

| | | Average days per week | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | >1 | >2 | >3 | >4 | 5 |
| **a.** | Food reheated for students' lunches | 1 | 0 | 0 | 0 | 0 | 0 |
| **b.** | 2 or more different main courses | 0 | 1 | 1 | 1 | 1 | 1 |
| **c.** | 2 or more different vegetables | 0 | 1 | 1 | 1 | 1 | 1 |
| **d.** | 2 or more different fruits | 0 | 1 | 1 | 1 | 1 | 1 |
| **e.** | Salad | 0 | 1 | 1 | 1 | 1 | 1 |
| **f.** | Whole grains | 0 | 1 | 1 | 1 | 1 | 1 |
| **g.** | Pizza | 1 | 0 | 0 | 0 | 0 | 0 |
| **h.** | Deep-fried French fried potatoes, included reheated | 1 | 0 | 0 | 0 | 0 | 0 |
| **i.** | Spaghetti or other pasta | 1 | 0 | 0 | 0 | 0 | 0 |
| **j.** | Cookies, crackers, pastries, cakes, other baked goods *not* low in fat | 1 | 0 | 0 | 0 | 0 | 0 |
| **k.** | Low fat or fat free cookies, crackers, pastries, cakes, other baked goods | 1 | 0 | 0 | 0 | 0 | 0 |
| **l.** | Ice cream or frozen yogurt *not* low in fat | 1 | 0 | 0 | 0 | 0 | 0 |
| **m.** | Low fat or fat free ice cream, frozen yogurt, sherbet | 1 | 0 | 0 | 0 | 0 | 0 |
| **n.** | A la carte lunch | 1 | 0 | 0 | 0 | 0 | 0 |

**8. What type of milk is available for students to purchase?**

**a.** ☐ Whole white milk — **d.** ☐ Flavored whole milk

**b.** ☐ Reduced fat or 1% white milk — **e.** ☐ Flavored reduced fat or 1% milk

**c.** ☐ Skim white milk — **f.** ☐ Flavored skim milk

#8-coding: Milk Availability

| | | | |
|---|---|---|---|
| 8.1: | Whole milk: | ☐ 0 = either a. &/or d. checked | ☐ 1 = both a. & d. unchecked |
| 8.2: | Flavored whole milk: | ☐ 0 = d. checked | ☐ 1 = d. unchecked |
| 8.3: | Low fat milk: | ☐ 0 = b., c., e., & f. all unchecked | ☐ 1 = either b., c., e., &/or f. checked |
| 8.4: | Low fat flavored milk: | ☐ 0 = either e. &/or f. checked | ☐ 1 = both e. & f. unchecked |

8.5: Only reduced fat, 1%, and/or skim white or flavored milk available:

☐ 0 = either a. &/or d. checked ☐ 1 = only either b., c., e., &/or f. checked

8.6: Only unflavored reduced fat, 1%, &/or skim white milk available:

☐ 0 = either a., d., e., &/or f. checked ☐ 1 = only either b. &/or c. checked

**9. What other beverages are available to students during lunch? Check all that apply.**

| | | | |
|---|---|---|---|
| **Fruit juice:** ........................ | ☐ **Yes** | ☐ **No** | ***If yes:*** (* if no, and check N/A for a. and b.) |
| **a.** 100% fruit juice | ☐ **Yes** (1) | ☐ **No** (0) | ☐ **N/A** (*) |
| **b.** <100% fruit juice | ☐ **Yes** (0) | ☐ **No** (1) | ☐ **N/A** (*) |
| **Other:** ........................ | ☐ **Yes** | ☐ **No** | ***If yes:*** (* if no, and check N/A for c. and d.) |
| **c.** Other sweetened beverages | ☐ **Yes** (0) | ☐ **No** (1) | ☐ **N/A** (*) |
| **d.** Water: | ☐ **Yes** (1) | ☐ **No** (0) | ☐ **N/A** (*) |

| | | |
|---|---|---|
| **0a. Is this observation being completed during a lunch period?** | ☐ Yes | ☐ No |
| **0b. Is this observation being completed while lunch food is present in the serving area?** | ☐ Yes | ☐ No |

**Observer name:** ______________________ **State** ______ **School ID#** ______________

Cafeteria Ambient Environment

**10. Please rate the following for the main CAFETERIA/EATING AREA** (or complete separate form for each area):

| | Great (1) | Good (1) | Fair (0) | Poor (0) | Other (*) |
|---|---|---|---|---|---|
| **a. Cafeteria temperature** | ☐ OK | | ☐ Hot or cold | | |
| **b. Air conditioning** | ☐ Yes | | ☐ No A/C | | |
| **c. Lighting** | ☐ Bright/OK | | ☐ Dark | | ☐ Lights off (*) |
| **d. Odor** | ☐ No smell or pleasant smell | ☐ Noticeable but not unpleasant odor | ☐ Slightly unpleasant odor | ☐ Strong, unpleasant odor | ☐ Yes ☐ No Is food present? (no coding) |
| **e. Noise** | ☐ Very quiet | ☐ Soft voices | ☐ Loud talking | ☐ Yelling/screaming | ☐ (*) No students present |
| **f. Music during meals?** | ☐ Yes | | ☐ No | | |

Cafeteria Appearance

**11. Please rate the following for the main CAFETERIA/EATING AREA** (or complete separate form for each area):

| | Great (1) | Good (1) | Fair (0) | Poor (0) | Other (*) |
|---|---|---|---|---|---|
| **a. Attractiveness** | ☐ Good physical condition, bright, clean, child appropriate | | ☐ Poor physical condition, dark, dirty, not child appropriate | | |
| **b. Physical structure** *(floors, walls, ceiling)* | ☐ Clean, well kempt, no damage or cracks | ☐ Stained but clean; no repair needed | ☐ Some damage, cracks, peeling paint | ☐ Unkempt, dirty, peeling paint, leaks, damaged | |
| **c. Clutter** | ☐ No clutter | ☐ Almost no clutter | ☐ Some clutter | ☐ Chaos | |
| **d. Cleanliness** | ☐ Clean | ☐ Almost all clean | ☐ Satisfactory | ☐ Dirty/moldy | |
| **e. Tables and seating condition** | ☐ Clean, no damage | ☐ Stained but clean; no damage | ☐ Stains, needs some repairs and paint | ☐ Dirty, damaged, paint needed | ☐ (*) Not set up during observation |
| **f. Furniture attractiveness** | ☐ Good physical condition, bright, clean, child appropriate | | ☐ Poor physical condition, dark, dirty, not child appropriate | | |

Cafeteria Layout

**12. Answer the following about the cafeteria LAYOUT:**

| | | | | |
|---|---|---|---|---|
| **a. Are any food or beverages visible from the cafeteria/eating area?** | ☐ (1) Yes, all | ☐ (1) No, all in separate room | ☐ (1) Fruit, vegetables, whole grains, skim white milk | ☐ (0) Only other items |
| **b. Are food vending machines visible from the cafeteria?** | ☐ Yes (0) | | ☐ No (1) | |
| **c. Are beverage vending machines visible from the cafeteria?** | ☐ Yes (0) | | ☐ No (1) | |

**Observer name:** ________________________________ **State** ______ **School ID#** ________________

**13a. Draw the shape of each cafeteria space (e.g., square, rectangle, L-shaped etc.). Number each wall and use these wall numbers in #6.**

*Space 1* *Space 2*

**13b. Measure the length of each wall** *(feet, inches)*. **Label these dimensions on the shapes drawn above.**

*13c.* Calculate the cafeteria area (SF): ______________________________________________________________

**13d. Measure the highest and lowest ceiling heights** *(feet, inches)*. *If ceiling heights are too high to measure, measure one cinder block, brick, or wall tile and count those, or estimate. Be sure to note when measurements are estimates.*

13d1. Ceiling height, high: ________FT _________ IN 13d2. Ceiling height, low: ________FT _________ IN

*13e. Calculate total wall area (multiply l x w x h of each wall and sum):* ________________________________________

*13f.* If Cafeteria area <u><</u>3,000 SF: 0 = ceiling height <12'-0" 1 = ceiling height <u>></u>12'-0"

If Cafeteria area >3,000 SF: 0 = ceiling height <14'-0" 1 = ceiling height <u>></u>14'-0"

**14a. For each wall, measure window heights** *(h)* **and widths** *(W)*. *For each window, measure, in feet and inches, the glass from top to bottom and left to right. Ignore any divisions in the glass within a single window. If you are unsure of how to measure, sketch the window and label its dimensions on the back of a page.*

| | | **H x W** (FT, IN) | | | | **H x W** (FT, IN) | |
|---|---|---|---|---|---|---|---|
| Wall 1 | Window 1 | _____________ | Quantity_____ | Wall 3 | Window 1 | _____________ | Quantity_____ |
| | Window 2 | _____________ | Quantity_____ | | Window 2 | _____________ | Quantity_____ |
| | Window 3 | _____________ | Quantity_____ | | Window 3 | _____________ | Quantity_____ |
| Wall 2 | Window 1 | _____________ | Quantity_____ | Wall 4 | Window 1 | _____________ | Quantity_____ |
| | Window 2 | _____________ | Quantity_____ | | Window 2 | _____________ | Quantity_____ |
| | Window 3 | _____________ | Quantity_____ | | Window 3 | _____________ | Quantity_____ |

*14b.* **Total window area:** For each window type, calculate the total area in SF (H x W X Quantity), then sum all:

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

*14c.* **Percent of cafeteria walls that are windows:** Total window area / total wall = ___________________________

**Enter 0** if the percentage is <10% (0.10) **Enter 1** if the percentage is <u>></u> 10% (0.25)

**Observer name:** ______________________________ **State** ________________ **School ID#**________

**Observe student circulation** *(path from entrance to food, seating, trash, exit)* **during lunch, or ask Food Service staff:**

**15a. Is the student circulation**

- ☐ Unclear: lots of overlapping paths and areas for congestion (0)
- ☐ Clear: no/ only minor overlapping: enter, food, seating, trash, exit without interfering paths or chaos (1)

**15b. Are there any obstructions in the cafeteria or serving area that affect movement (e.g., columns, piers, pipes)?**

- ☐ Yes (0) (specify: ________________________________________)
- ☐ No (1)

Cafeteria Furniture

**16. Answer the following about cafeteria FURNITURE** *(see pg. 8 for #16h. crowding SF calculation instructions)*:

| | | | |
|---|---|---|---|
| **a. Are all student tables and chairs the same?** | ☐ Yes | | ☐ No |
| **b. Count the number of tables and chairs** | 16b1. # Table type 1: ____________<br>16b2. # Table type 2: ____________ | | 16b3. # Chairs/table type 1: ________ *(quantity or "benches")*<br>16b4. # Chairs/table type 2: ________ *(quantity or "benches")* |
| **c. Table shape** *(square, circle, rectangle)*<br>16c. 0=rectangle only 1=some or all round/square | 16c1. Table type 1: ____________ | | 16c2. Table type 2: ____________ |
| **d. Do students sit on individual seats or benches?** | ☐ (0) Benches | ☐ (1) Individual Seats | ☐ (1) Both |
| **e. Are seats attached to the tables?** | ☐ (0) Yes | ☐ (1) No | ☐ (1) Both |
| **f. Is there a "sharing" table where students can leave or take uneaten food items?** | ☐(1) Yes | | ☐(0) No |

16g. Crowding Table: Divide total # students/# meal periods/# tables= ________________________________________

☐ 0 if answer is >10 students per table ☐ 1 if answer is ≤10 students per table:

Cafeteria Fenestration

**17. Please answer the following questions about cafeteria WINDOWS:**

| | (1) | (0) | (0) |
|---|---|---|---|
| **a. Does the cafeteria have windows?** | ☐ Yes | ☐ No | |
| **b. Rate the condition of the windows** | ☐ Clean, not broken or damaged, transparent; only minor cleaning, painting, or repairs needed | ☐ Dirty, cracked, damaged, or broken; peeling paint; not transparent | ☐ No windows |
| **c. Is the view from the cafeteria/ eating area windows** *(sky, trees, grass, water)*: | ☐ More than ½ natural | ☐ Less than ½ natural; no view | ☐ No windows |
| **d. Are the windows operable?** | ☐ All, some | ☐ None | ☐ No windows |
| **e. Are the windows transparent** *(i.e., not tinted, opaque, or too dirty to see through)?* | ☐ All, some | ☐ None are transparent | ☐ No windows |
| **f. Do windows have treatments such as blinds, curtains, or shades?** | ☐ All, some | ☐ No treatments | ☐ No windows |
| **g. Do the windows have screens?** | ☐ All, some | ☐ No screens | ☐ No windows |

**Observer name:** ______________________________ **State** _______________ **School ID#** _______

Advertisements – Cafeteria and serving areas

**18. Inside the CAFETERIA AND SERVING AREA, are advertisements and/or signage visible for:** ☺

| Topic | Yes | No | Quantity # | Content *Food, PA, both* | Messages *[info (food pyramid); advertising a product (Coke); take action (eat more veggies); celebrity role model]* | Location *(serving area, cafeteria, wall, eye level, too high to see, other)* |
|---|---|---|---|---|---|---|
| | 1 | | 2 | | | 3 |
| a. Soft drinks, brand name foods, flyers for fundraisers w/ food | 0 ☐ | 1 ☐ | | | | |
| b. Healthy eating and physical activity (PA) promotion | 1 ☐ | 0 ☐ | | | | |

**Kitchen/Prep Area**

**19. Please rate and answer the following for the KITCHEN/PREPARATION AREAS:**

| | Great (1) | Good (1) | Fair (0) | Poor (0) | N/A (*) |
|---|---|---|---|---|---|
| **a. Is there a kitchen?** | ☐ Yes | | ☐ No *(If no, check "N/A" for b.-d., f.-h.)* | | |
| **b. Attractiveness** | ☐ Good condition, bright, clean, child friendly | | ☐ Poor condition, dark, dirty, not child friendly | | ☐ N/A |
| **c. Physical structure** *(floors, walls, ceiling)* | ☐ Clean, well kempt, no damage or cracks | ☐ Stained but clean; no repair needed | ☐ Some damage, cracks, peeling paint | ☐ Unkempt, dirty, damaged, peeling paint | ☐ N/A |
| **d. Kitchen equipment** *Sink, stove/oven, freezers, refrigerators, mixers* | ☐ Clean, not damaged | ☐ Stained but clean; not damaged | ☐ Some stains and damage | ☐ Dirty, damaged, repairs needed | ☐ N/A |
| **e. Lighting** | ☐ Bright/ok | | ☐ Dark | | ☐ Lights off |
| **f. Windows present?** | ☐ Yes | | ☐ No | | ☐ N/A |
| **g. Cleanliness** | ☐ Clean | ☐ Almost all clean | ☐ Satisfactory | ☐ Dirty/moldy | ☐ N/A |
| **h. Clutter** | ☐ No clutter | ☐ Almost no clutter | ☐ Some clutter | ☐ Chaos | ☐ N/A |

**Serving Area**

**20. Note where the serving area is located:**

☐ **Inside the cafeteria/eating area** ☐ **A space separated by at least a door/opening from the cafeteria**

☐ **A serving window** ☐ **A separate space, but the fruit/salad bar is in the cafeteria**

**21. Locate the student menu.**

**a. Are menu items named:**

☐ **By item** *(e.g., "carrots")* (0) ☐ **Descriptively** *(e.g. "freshly picked carrots")* (1) ☐ **Creatively** *(e.g., "power sticks")* (1)

**b. If the student menu is in the cafeteria or serving area, is it visible:**

☐ Students preorder meals ahead of time (menu may or may not be posted) (1)

☐ Before students are served, along the circulation path (e.g., on the door into the serving area) (1)

☐ Only visible once students are in line being served items (0)

☐ Posted, but too far away or too high to read (0)

☐ No menu is posted in the cafeteria or serving area, and there is no preordering (0)

**Observer name:** ______________________________ **State** ______________ **School ID#**_______

**22. Please rate the following for the SERVING AREA:**

| | Great (1) | Good (1) | Fair (0) | Poor (0) | N/A (*) |
|---|---|---|---|---|---|
| **a. Attractiveness** | ☐ Good condition, bright, clean, child appropriate | | ☐ Poor condition, dark, dirty, not child appropriate | | |
| **b. Physical structure** *Floors, walls, ceiling* | ☐ Clean, well kempt, no damage or cracks | ☐ Stained but clean; no repair needed | ☐ Some damage, cracks, peeling paint | ☐ Unkempt, dirty, damaged, peeling paint | |
| **c. Equipment condition** *Counters, display, shelves etc.* | ☐ Clean, well kempt, no damage | ☐ Stained but clean; no repair needed | ☐ Some repair or cleaning needed | ☐ Unkempt, dirty, damaged | |
| **d. Lighting** | ☐ Bright | | ☐ Dark | | ☐ Lights off |
| **e. Cleanliness** | ☐ Clean | ☐ Almost all clean | ☐ Satisfactory | ☐ Dirty/moldy | |
| **f. Clutter** | ☐ No clutter | ☐ Almost no clutter | ☐ Some clutter | ☐ Chaos | |
| **g. Food attractiveness** | ☐ Fresh, colorful, creatively and cleanly presented | ☐ Most items fresh, colorful, cleanly presented | ☐ Some items fresh, colorful, cleanly presented | ☐ Not fresh, bland colors, unattractive presentation | |

**23. Please answer the following questions about the SERVING AREA:**

| | (0) | | (1) |
|---|---|---|---|
| **a. Is one of the $1^{st}$ three items students see as they enter the serving area a fruit or vegetable?** | ☐ No | | ☐ Yes |
| **b. Students use serving trays (vs. just plates/bowls)** | ☐ No | | ☐ Yes |
| **c.*** *If yes, how many lunch tray colors are available?* | ☐ Only 1 color | | ☐ More than 1 color |
| **d.*** *If b=yes, what is the lunch tray material?* | ☐ Styrofoam, cardboard (bendable) | | ☐ Plastic (not bendable) |
| **e. Tray rests are available in front of serving stations** | ☐ No | | ☐ Yes |
| **f. Students make multiple serving trips (vs. only one time through checkout line allowed)** | ☐ Yes, for all items | | ☐ No; only for certain items |
| **g.*** *If yes, students make multiple serving trips for* FV/healthy items only (* if f=no) | ☐ No | | ☐ Yes, for fruits, vegetables, whole grains, LF white milk |
| **h. Individual food items in the serving area are labeled** | ☐ No, none | | ☐ Yes, some or all |
| **i.* Fresh fruits are located next to the checkout station** | ☐ No | ☐ no fresh fruit* | ☐ Yes |
| **j. Ice cream is available to students** | ☐ Yes | | ☐ No |
| **k.*** *If yes, the ice cream cooler lid is* (if no, *): | ☐ Transparent | | ☐ Opaque |
| **l. Some/all unhealthy foods or snacks are located out of reach (e.g., behind counter) or by request only** | ☐ No | ☐ N/A* (no unhealthy foods) | ☐ Yes |

**24. Measure the length and width of each *size* of lunch tray available to students** (* if no trays are used).

L ________ in x W ________ in = ________in$^2$   L ________ in x W ________ in = ________in$^2$

L ________ in x W ________ in = ________in$^2$   L ________ in x W ________ in = ________in$^2$

Calculate the lunch tray area. If there is more than one tray size, average the areas: ________________________

Enter 0 if the area is $\leq$ 100 in$^2$   Enter 1 if the area is > 100 in$^2$

**25. Locate utensils available to students. Are plastic forks, spoons, and knives, or all needed utensils for the meal(s) being served available?** ☐ **Yes** (1) ☐ **No** (0)

**Observer name:** ______________________ **State** ____________ **School ID#**_______

**26. Answer the following about fresh fruit:**

a. Is fresh fruit offered? ☐ Yes (0) ☐ No (1)

b. Fresh fruit is served from a: ☐ Metal/plastic tray (0) ☐ Decorative bowl/display (1) ☐ N/A (*)

c. Fresh fruit is served: ☐ Sliced (1) ☐ Whole (0) ☐ Both (1) ☐ N/A (*)

**27. How are the following foods served and presented** *(check all that apply)*?

| Item | Individual Pre-measured or plated servings | Served from larger trays, bowls, or pots | Wrapped or covered, transparent | Wrapped or covered, NOT transparent | N/A |
|---|---|---|---|---|---|
| a. Fruits & vegetables | ☐ 0 | ☐ 1 | ☐ 1 | ☐ 0 | ☐* |
| b. Desserts | ☐ 1 | ☐ 0 | ☐ 0 | ☐ 1 | ☐* |
| c. Snack items *e.g., chips* | ☐ 1 | ☐ 0 | ☐ 0 | ☐ 1 | ☐* |

**28. Locate the milk cooler from which students are served. Count the visible flavored and unflavored milk crates.**

Is at least 50% of the milk visible to students when serving white, unflavored milk? ☐ Yes (1) ☐ No (0)

**29. Answer the following about the milk layout, observing the order/direction students move in the serving line:**

a. Is the low fat, unflavored milk:
- ☐ Only low fat, unflavored milk offered (1)
- ☐ Behind flavored milk, not first in line (0)
- ☐ In front of flavored milk, not first in line (1)
- ☐ Behind flavored milk, first in line (0)
- ☐ In front of flavored milk, first in line (1)

b. Is the white milk:
- ☐ Only white milk offered (1)
- ☐ Behind flavored milk, not first in line (0)
- ☐ In front of flavored milk, not first in line (1)
- ☐ Behind flavored milk, first in line (0)
- ☐ In front of flavored milk, first in line (1)

**30. If observing during a meal time, or if lunch tray photos are available:**

30a. <u>All/most</u> students have ≥1 side fruit on their lunch tray at check out ☐ Yes (1) ☐ No (0)

30b. <u>All/most</u> students have ≥1 side vegetable on their lunch tray at check out ☐ Yes (1) ☐ No (0)

30c. Total number of side fruits and vegetables offered during the meal (salad, applesauce, corn, carrots):_________

***Are at least half (50%) of the items RAW?*** ☐ Yes (1) ☐ No (0)

30d. Are any meal items breaded or fried (e.g., chicken fingers, mozzarella sticks)? ☐ Yes (0) ☐ No (1)

---

**16h.** *Select the required* **SF/student** *value based on table & chair type (see #16). Use this value in the following equations:*

<u>Rectangular table</u>: attached seats = **10 SF/student**; stackable chairs = **11 SF/student**

<u>Round table</u> (or square): attached seats = **14 SF/student**; stackable chairs = **15 SF/student**

<u>If</u> all tables/chairs are the <u>same</u>: (1g. # students) / (1i. # meal periods) * (SF/student) = required SF

---

<u>If</u> all tables/chairs are <u>not</u> the same: [1g. / 1i. * SF/student * 16b<u>1</u>. / (16b1. + 16b2.)] +
[1g. / 1i. * SF/student * 16b<u>2</u>. / (16b1. + 16b2.)] = required SF

---

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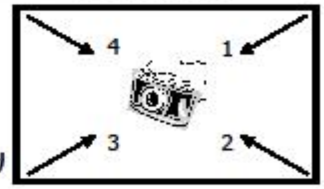
Cafeteria crowding (SF) coding: 0 = if (13c. actual SF) < required SF 1 = if (13c. actual SF) ≥ required SF

## APPENDIX F *(continued)*

**Observer name:** ____________________ **State** __________ **School ID#** ______

**31. Please take photos^ of the following spaces/items:**




- ☐ (4) ***Kitchen and food preparation areas***
- ☐ (4) ***Food/beverage serving areas***
- ☐ (All) ***Food/beverage serving stations (see example below)***
- ☐ (4) ***Cafeteria/eating areas***
- ☐ ***Photograph a student serving tray next to a ruler (one per tray size and color)***

*^ Stand near one corner at a time in each space, face the opposite corner, and take a photo. Repeat for all corners (examples below). The entire room should be captured, and each photo should contain both floor and ceiling.*

*^ If children are present during photography, NO FACES may be photographed.*

***Cafeteria example photos:***

**Corner 1**

**Corner 2**

**Corner 3**

**Corner 4**

***Serving station example photos (be sure to label each item in your sketches on p. 11)***


- CAFES p. 9 of 11 -

# APPENDIX F *(continued)*

**Observer name:** ______________________________ **State** ______ **School ID#**________

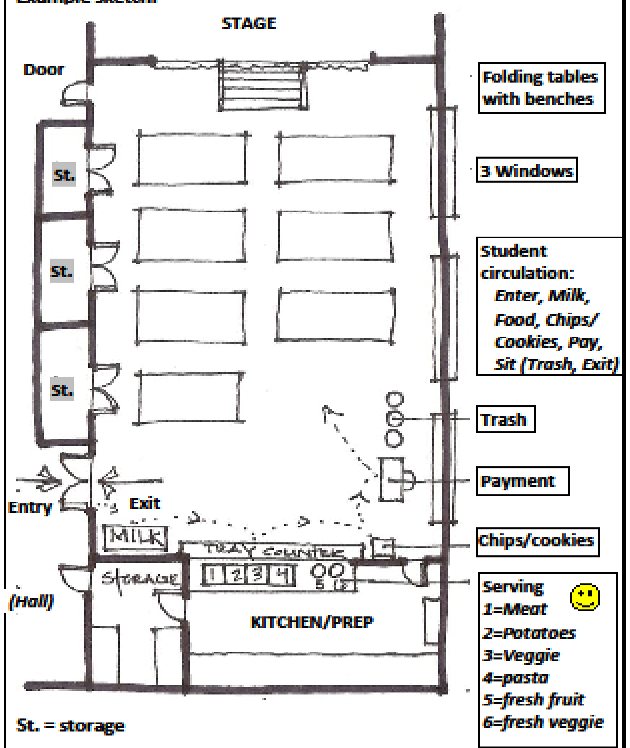
**32. Below, please *sketch and label* the food/beverage preparation (kitchen), serving, and eating areas (cafeteria).**

1. Draw the walls.
2. Draw doors/windows.
3. Draw the furniture.

5. Draw and label:

- ☐ *Kitchen/prep area*
- ☐ *Serving area*
- ☐ *Menu locations (M)*
- ☐ *Storage areas*
- ☐ *Student entry/exit*
- ☐ *Number all food/beverage locations (#)*
- ☐ *Payment location*
- ☐ *Student circulation paths: entry, seating, food/bev, payment, trash, exit*
- ☐ *Disposal/trash area*
- ☐ *Tables and seating (draw exact number of tables, note # chairs, bench)*
- ☐ *Healthy food and PA signage (S)*

**Example sketch:**

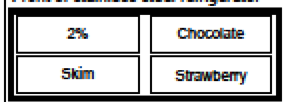


## APPENDIX F *(continued)*

**Observer name:** ______________________ **State** ____________ **School ID#**_______

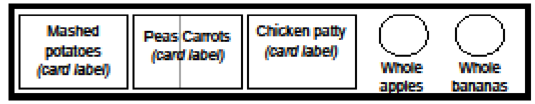
**33. Below, please photograph, sketch, AND label *each* food and beverage serving location according to the instructions.**

**Example sketch: #n/a. MILK refrigerator**
*Front of stainless steel refrigerator*




*View after student lifts opaque top; beverage label is printed on cardboard cartons; cartons are all the same except for label color/text*

**Example sketch: #1-6. Warm food serving station; fruit bowls**
*Front*




*Metal trays, uncovered, not behind glass on metal counter top; food items labeled cover descriptively on white card with black handwritten text*

*Opaque red glass bowls on metal labeled counter, no item label*

**INSTRUCTIONS:**

Carefully *photograph* each food and beverage serving location numbered on your previous sketch.

*Sketch* each food and beverage serving location numbered on your previous sketch:

**A. List # from previous sketch**

**B. Title the station**

**C. Draw the station**

D. Label individual items

**E. Are individual items labeled?** If yes, describe item labels.

F. Describe how each item is served:
- *Container type*
  *e.g. tray, bowl, basket, pot*
- *Container material*
  *e.g. metal, glass, plastic*
- *Is container transparent or opaque?*
- Is the container *covered* (*i.e., students have to remove before serving*)?
- Is the *cover opaque* or *transparent*?
- **Are students served or serve themselves?**
- **Are items pre-portioned?**
- **Describe surfaces below serving containers and materials** *e.g., Metal or glass counter, plastic/metal*

## **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| *N/A* | *N/A* | | *0a* | *Observation during lunch time* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *0b* | *Observation when lunch food present* | | | | | *N/A* | *N/A* | |
| 1 | 1 | | 1a | Vending machines available to students during lunch | | Availability | | | yes | no | |
| | 1 | 1 | 1b | FV available in vending machines | | Availability | | | no | yes | |
| 1 | 1 | | 1c | Fundraisers w/ food during lunch | | Availability | | | yes | no | |
| 1 | 1 | | 1d | Fundraisers w/ food during lunch in cafeteria | | Availability | | | yes | no | |
| 1 | 1 | 1 | 1e | Different portion sizes available by grade | | Availability | | | no | yes | Based on USDA guidelines:<br>Grades K-3 (~ages 4-8)<br>Grades 4-6 (~ages 9-13)<br>Grades 7+ (~ages 14+) |
| *N/A* | *N/A* | | *1f* | *Lunches prepped by outside company* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *1g* | *Student population* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *1h* | *Students/meal period* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *1i* | *# meal periods* | | | | | *N/A* | *N/A* | |
| 1 | 1 | | 2 | Lunch cooked at school (not just reheated) | Kitch & Serv | | | | no | yes | |
| 1 | 1 | | 3a | Suitable equipment availability helped us offer healthy options in last year | Kitch & Serv | | | | unchecked | checked | |
| 1 | 1 | | 3b | Storage space availability helped us offer healthy options in last year | Kitch & Serv | | | | unchecked | checked | |
| 1 | 1 | | 4a | Lack of prep area limited healthy option offerings In last year | Layout | | | | checked | unchecked | |
| 1 | 1 | | 4b | Lack of display space limited healthy option offerings In last year | Layout | | | | checked | unchecked | |
| 1 | 1 | | 4c | Lack of storage space limited healthy option offerings In last year | Kitch & Serv | | | | checked | unchecked | |
| 1 | 1 | | 5a | Self serve a la carte lunch entrees | | Serv method | | | checked | unchecked | |
| 1 | 1 | | 5b | Self serve a la carte lunch sides | | Serv method | | | checked | unchecked | |
| 1 | 1 | | 5c | Self-serve salad | | Serv method | | | unchecked | checked | |
| | 1 | | 5d | No a la carte items available | | Serv method | | | checked | unchecked | |

## APPENDIX G: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| | 1 | | 6a | Offer vs. serve: a la carte entree | | Serv method | | | checked | unchecked | |
| | 1 | | 6b | Offer vs. serve: a la carte side | | Serv method | | | checked | unchecked | |
| | 1 | | 6c | Offer vs. serve: salad/fruit | | Serv method | | | unchecked | checked | |
| | 1 | | 6d | Offer vs. serve: none | | Serv method | | | checked | unchecked | |
| 1 | 1 | | 7a0 | <=0 days/avg week: reheat meals | | | | Food | not circled | circled | |
| | 1 | | 7a1 | >=1 day/avg week: reheat meals | | | | Food | circled | not circled | |
| | 1 | | 7a2 | >=2 days/avg week: reheat meals | | | | Food | circled | not circled | |
| | 1 | | 7a3 | >=3 days/avg week: reheat meals | | | | Food | circled | not circled | |
| | 1 | | 7a4 | >=4 days/avg week: reheat meals | | | | Food | circled | not circled | |
| | 1 | | 7a5 | >=5+ days/avg week: reheat meals | | | | Food | circled | not circled | |
| | 1 | | 7b0 | <=0 days/avg week: 2+ entrees | | Variety | | | circled | not circled | |
| 1 | 1 | | 7b1 | >=1 day/avg week: 2+ entrees | | Variety | | | not circled | circled | |
| 1 | 1 | | 7b2 | >=2 days/avg week: 2+ entrees | | Variety | | | not circled | circled | |
| 1 | 1 | | 7b3 | >=3 days/avg week: 2+ entrees | | Variety | | | not circled | circled | |
| 1 | 1 | | 7b4 | >=4 days/avg week: 2+ entrees | | Variety | | | not circled | circled | |
| 1 | 1 | | 7b5 | >=5+ days/avg week: 2+ entrees | | Variety | | | not circled | circled | |
| | 1 | | 7c0 | <=0 days/avg week: 2+ veggies | | Variety | | | circled | not circled | |
| 1 | 1 | | 7c1 | >=1 day/avg week: 2+ veggies | | Variety | | | not circled | circled | |
| 1 | 1 | | 7c2 | >=2 days/avg week: 2+ veggies | | Variety | | | not circled | circled | |
| 1 | 1 | | 7c3 | >=3 days/avg week: 2+ veggies | | Variety | | | not circled | circled | |
| 1 | 1 | | 7c4 | >=4 days/avg week: 2+ veggies | | Variety | | | not circled | circled | |
| 1 | 1 | | 7c5 | >=5+ days/avg week: 2+ veggies | | Variety | | | not circled | circled | |
| | 1 | | 7d0 | <=0 days/avg week: 2+ fruits | | Variety | | | circled | not circled | |
| 1 | 1 | | 7d1 | >=1 day/avg week: 2+ fruits | | Variety | | | not circled | circled | |
| 1 | 1 | | 7d2 | >=2 days/avg week: 2+ fruits | | Variety | | | not circled | circled | |
| 1 | 1 | | 7d3 | >=3 days/avg week: 2+ fruits | | Variety | | | not circled | circled | |
| 1 | 1 | | 7d4 | >=4 days/avg week: 2+ fruits | | Variety | | | not circled | circled | |
| 1 | 1 | | 7d5 | >=5+ days/avg week: 2+ fruits | | Variety | | | not circled | circled | |
| 1 | 1 | | 7e0 | <=0 days/avg week: Salad Bar | | Availability | | | circled | not circled | |
| 1 | 1 | | 7e1 | >=1 day/avg week: Salad Bar | | Availability | | | not circled | circled | |

## **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| 1 | 1 | | 7e2 | >=2 days/avg week: Salad Bar | | Availability | | | not circled | circled | |
| 1 | 1 | | 7e3 | >=3 days/avg week: Salad Bar | | Availability | | | not circled | circled | |
| | 1 | | 7e4 | >=4 days/avg week: Salad Bar | | Availability | | | not circled | circled | |
| 1 | 1 | | 7e5 | >=5+ days/avg week: Salad Bar | | Availability | | | not circled | circled | |
| 1 | 1 | | 7f0 | <=0 days/avg week: whole grains | | Availability | | | circled | not circled | |
| 1 | 1 | | 7f1 | >=1 day/avg week: whole grains | | Availability | | | not circled | circled | |
| 1 | 1 | | 7f2 | >=2 days/avg week: whole grains | | Availability | | | not circled | circled | |
| 1 | 1 | | 7f3 | >=3 days/avg week: whole grains | | Availability | | | not circled | circled | |
| | 1 | | 7f4 | >=4 days/avg week: whole grains | | Availability | | | not circled | circled | |
| 1 | 1 | | 7f5 | >=5+ days/avg week: whole grains | | Availability | | | not circled | circled | |
| 1 | 1 | | 7g0 | <=0 days/avg week: pizza | | Availability | | | not circled | circled | |
| 1 | 1 | | 7g1 | >=1 day/avg week: pizza | | Availability | | | circled | not circled | |
| 1 | 1 | | 7g2 | >=2 days/avg week: pizza | | Availability | | | circled | not circled | |
| 1 | 1 | | 7g3 | >=3 days/avg week: pizza | | Availability | | | circled | not circled | |
| | 1 | | 7g4 | >=4 days/avg week: pizza | | Availability | | | circled | not circled | |
| 1 | 1 | | 7g5 | >=5+ days/avg week: pizza | | Availability | | | circled | not circled | |
| 1 | 1 | | 7h0 | <=0 days/avg week: French fried potatoes | | Availability | | | not circled | circled | |
| 1 | 1 | | 7h1 | >=1 day/avg week: French fried potatoes | | Availability | | | circled | not circled | |
| 1 | 1 | | 7h2 | >=2 days/avg week: French fried potatoes | | Availability | | | circled | not circled | |
| 1 | 1 | | 7h3 | >=3 days/avg week: French fried potatoes | | Availability | | | circled | not circled | |
| | 1 | | 7h4 | >=4 days/avg week: French fried potatoes | | Availability | | | circled | not circled | |
| 1 | 1 | | 7h5 | >=5+ days/avg week: French fried potatoes | | Availability | | | circled | not circled | |
| 1 | 1 | | 7i0 | <=0 days/avg week: pasta | | Availability | | | not circled | circled | |
| 1 | 1 | | 7i1 | >=1 day/avg week: pasta | | Availability | | | circled | not circled | |
| 1 | 1 | | 7i2 | >=2 days/avg week: pasta | | Availability | | | circled | not circled | |

## **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| 1 | 1 | | 7i3 | >=3 days/avg week: pasta | | Availability | | | circled | not circled | |
| | 1 | | 7i4 | >=4 days/avg week: pasta | | Availability | | | circled | not circled | |
| 1 | 1 | | 7i5 | >=5+ days/avg week: pasta | | Availability | | | circled | not circled | |
| 1 | 1 | | 7j0 | <=0 days/avg week: Cookies, crackers, pastries, cakes, baked goods NOT LF | | Availability | | | not circled | circled | |
| 1 | 1 | | 7j1 | >=1 day/avg week: Cookies, crackers, pastries, cakes, baked goods NOT LF | | Availability | | | circled | not circled | |
| 1 | 1 | | 7j2 | >=2 days/avg week: Cookies, crackers, pastries, cakes, baked goods NOT LF | | Availability | | | circled | not circled | |
| 1 | 1 | | 7j3 | >=3 days/avg week: Cookies, crackers, pastries, cakes, baked goods NOT LF | | Availability | | | circled | not circled | |
| | 1 | | 7j4 | >=4 days/avg week: Cookies, crackers, pastries, cakes, baked goods NOT LF | | Availability | | | circled | not circled | |
| 1 | 1 | | 7j5 | >=5+ days/avg week: Cookies, crackers, pastries, cakes, baked goods NOT LF | | Availability | | | circled | not circled | |
| 1 | 1 | | 7k0 | <=0 days/avg week: Low-fat cookies, crackers, cakes, pastries, baked goods | | Availability | | | not circled | circled | |
| 1 | 1 | | 7k1 | >=1 day/avg week: Low-fat cookies, crackers, cakes, pastries, baked goods | | Availability | | | circled | not circled | |
| 1 | 1 | | 7k2 | >=2 days/avg week: Low-fat cookies, crackers, cakes, pastries, baked goods | | Availability | | | circled | not circled | |
| 1 | 1 | | 7k3 | >=3 days/avg week: Low-fat cookies, crackers, cakes, pastries, baked goods | | Availability | | | circled | not circled | |
| | 1 | | 7k4 | >=4 days/avg week: Low-fat cookies, crackers, cakes, pastries, baked goods | | Availability | | | circled | not circled | |
| 1 | 1 | | 7k5 | >=5+ days/avg week: Low-fat cookies, crackers, cakes, pastries, baked goods | | Availability | | | circled | not circled | |
| 1 | 1 | | 7l0 | <=0 days, avg week: Ice cream, frozen yogurt NOT low in fat | | Availability | | | not circled | circled | |
| 1 | 1 | | 7l1 | >=1 day, avg week: Ice cream, frozen yogurt NOT low in fat | | Availability | | | circled | not circled | |
| 1 | 1 | | 7l2 | >=2 days, avg week: Ice cream, frozen yogurt NOT low in fat | | Availability | | | circled | not circled | |

## **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| 1 | 1 | | 7l3 | >=3 days, avg week: Ice cream, frozen yogurt NOT low in fat | | Availability | | | circled | not circled | |
| | 1 | | 7l4 | >=4 days, avg week: Ice cream, frozen yogurt NOT low in fat | | Availability | | | circled | not circled | |
| 1 | 1 | | 7l5 | >=5+ days, avg week: Ice cream, frozen yogurt NOT low in fat | | Availability | | | circled | not circled | |
| 1 | 1 | | 7m0 | <0 days/avg week: Low fat ice cream/frozen yogurt | | Availability | | | not circled | circled | |
| 1 | 1 | | 7m1 | >=1 day/avg week: Low fat ice cream/frozen yogurt | | Availability | | | circled | not circled | |
| 1 | 1 | | 7m2 | >=2 days/avg week: Low fat ice cream/frozen yogurt | | Availability | | | circled | not circled | |
| 1 | 1 | | 7m3 | >=3 days/avg week: Low fat ice cream/frozen yogurt | | Availability | | | circled | not circled | |
| | 1 | | 7m4 | >=4 days/avg week: Low fat ice cream/frozen yogurt | | Availability | | | circled | not circled | |
| 1 | 1 | | 7m5 | >=5+ days/avg week: Low fat ice cream/frozen yogurt | | Availability | | | circled | not circled | |
| 1 | 1 | | 7n0 | <=0 days/avg week: a la carte lunch | | Availability | | | not circled | circled | |
| | 1 | | 7n1 | >=1 day/avg week: a la carte lunch | | Availability | | | circled | not circled | |
| | 1 | | 7n2 | >=2 days/avg week: a la carte lunch | | Availability | | | circled | not circled | |
| | 1 | | 7n3 | >=3 days/avg week: a la carte lunch | | Availability | | | circled | not circled | |
| | 1 | | 7n4 | >=4 days/avg week: a la carte lunch | | Availability | | | circled | not circled | |
| | 1 | | 7n5 | >=5+ days/avg week: a la carte lunch | | Availability | | | circled | not circled | |
| 1 | 1 | | 8.1 | Whole milk offered | | Availability | | | yes | no | See CAFES form for coding |
| 1 | 1 | | 8.2 | Flavored whole milk offered | | Availability | | | yes | no | See CAFES form for coding |
| 1 | 1 | | 8.3 | Skim &/or red fat offered | | Availability | | | no | yes | See CAFES form for coding |
| 1 | 1 | | 8.4 | Flavored skim &/or red fat offered | | Availability | | | yes | no | See CAFES form for coding |
| 1 | 1 | | 8.5 | ONLY LF milk offered | | Availability | | | no | yes | See CAFES form for coding |
| 1 | 1 | | 8.6 | ONLY unflavored LF milk offered | | Availability | | | no | yes | See CAFES form for coding |
| | 1 | 1 | 9a | 100% fruit juice offered | | Availability | | | no | yes | |
| | 1 | 1 | 9b | <100% fruit juice offered | | Availability | | | yes | no | |

# **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **CAFES study** | **Final CAFES** | | | | **ROOM** (subscale) | **TABLE** (subscale) | **PLATE** | **FOOD** | **0** | **1** | |
| | 1 | 1 | 9c | Other sweetened beverage available | | Availability | | | yes | no | |
| | 1 | 1 | 9d | Water availability | | Availability | | | no | yes | |
| 1 | 1 | | 10a | Cafeteria temperature | Ambient | | | | hot/cold | OK | |
| 1 | 1 | | 10b | Cafeteria A/C | Ambient | | | | no | yes | |
| | 1 | 1 | 10c | Cafeteria lighting | Ambient | | | | dark | bright/OK | |
| 1 | 1 | | 10d | Cafeteria odor | Ambient | | | | fair/poor | great/good | |
| | 1 | 1 | 10e | Cafeteria noise | Ambient | | | | fair/poor | great/good | |
| 1 | 1 | | 10f | Cafeteria music | Ambient | | | | no | yes | |
| 1 | 1 | | 11a | Cafeteria attractiveness | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 11b | Cafeteria physical structure | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 11c | Cafeteria clutter | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 11d | Cafeteria cleanliness | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | 1 | 11e | Cafeteria furniture condition | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 11f | Cafeteria furniture attractiveness | | Furniture | | | fair/poor | great/good | |
| 1 | 1 | | 12a | Food/bev visibility from Café | Layout | | | | All; none; FV, milk, whole grains only | Only "other" (unhealthy) items | |
| 1 | 1 | | 12b | Food vending visibility from cafeteria | Layout | | | | yes | no | |
| 1 | 1 | | 12c | Beverage vending visibility from cafeteria | Layout | | | | yes | no | |
| *N/A* | *N/A* | | *13a* | *Draw floor plan outline* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *13b* | *Wall measurements* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *13c* | *Cafeteria area (SF)* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *13d1* | *Cafeteria ceiling height, high* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *13d2* | *Cafeteria ceiling height, low* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *13e* | *Cafeteria wall area (SF)* | | | | | *N/A* | *N/A* | |
| 1 | 1 | | 13f | Cafeteria ceiling height | Ambient | | | | below standard | = or above standard | If area ≤3000SF: ≥12' height<br>If area >3000SF: ≥14'' height |
| *N/A* | *N/A* | | *14* | *Window measurements* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *14b* | *Total window area* | | | | | *N/A* | *N/A* | |
| 1 | 1 | | 14c | % cafeteria wall area = window | Fenestration | | | | <0.10 (10%) | ≥0.10 (10%) | Based on CAFES study sample |

# **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| 1 | 1 | | 15a | Student circulation | Layout | | | | unclear | clear | |
| 1 | 1 | | 15b | Cafeteria floor plan obstructions | Layout | | | | yes | no | |
| *N/A* | *N/A* | | *16a* | *Tables/chairs are same* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *16b1* | *# Table type 1* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *16b2* | *# Table type 2* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *16b3* | *# Chairs/benches, table type 1* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *16b4* | *# Chairs/benches, table type 2* | | | | | *N/A* | *N/A* | |
| 1 | 1 | | 16c | Cafeteria table shape | | Furniture | | | rectangle only | some/all round, square | |
| *N/A* | *N/A* | | *16c1* | *Table type 1 shape* | | | | | *N/A* | *N/A* | |
| *N/A* | *N/A* | | *16c2* | *Table type 2 shape* | | | | | *N/A* | *N/A* | |
| 1 | 1 | | 16d | Cafeteria benches or indiv. seats/chairs | | Furniture | | | benches | individual seats, both | |
| 1 | 1 | | 16e | Cafeteria seating attached | | Furniture | | | yes | no, both | |
| | 1 | | 16f | Sharing table presence | | Serv method | | | no | yes | |
| 1 | 1 | | 16g | Crowding (table) | Ambient | | | | >10/table | ≤10/table | students/table/meal period |
| 1 | 1 | | 16h | Crowding (SF) | Ambient | | | | below standard | = or above standard | See CAFES form p. 8 for coding |
| 1 | 1 | | 17a | Cafeteria window presence | Fenestration | | | | no | Yes | |
| 1 | 1 | | 17b | Cafeteria window condition | Fenestration | | | | dirty, damaged | clean, no damage | |
| 1 | 1 | | 17c | Cafeteria window view | Fenestration | | | | >1/2 natural | <1/2 natural, no windows | |
| 1 | 1 | | 17d | Cafeteria windows operable | Fenestration | | | | all/some | yes | |
| 1 | 1 | | 17e | Cafeteria windows transparent | Fenestration | | | | all/some | yes | |
| 1 | 1 | | 17f | Cafeteria window blinds, curtains, shades | Fenestration | | | | all/some | yes | |
| 1 | 1 | | 17g | Cafeteria window screens | Fenestration | | | | all/some | yes | |
| | 1 | | 18a1 | Unhealthy ads/signage | Ads | | | | yes | no | |
| | 1 | | 18a2 | Unhealthy ad quantity | Ads | | | | >1 | ≤1 | |
| | 1 | | 18a3 | Unhealthy ad location | Ads | | | | cafeteria, serving area | other | |

# **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| 1 | 1 | | 18b1 | Healthy ads/signage | Ads | | | | no | yes | |
| | 1 | | 18b2 | Healthy ad quantity | Ads | | | | ≤1 | >1 | |
| | 1 | | 18b3 | Healthy ad location | Ads | | | | not visible by students (high, staff office) | cafeteria, serving area | |
| 1 | 1 | | 19a | Kitchen presence | Kitch & Serv | | | | no | yes | |
| 1 | 1 | 1 | 19b | Kitchen attractiveness | Kitch & Serv | | | | fair/poor | great/good | |
| 1 | 1 | 1 | 19c | Kitchen condition | Kitch & Serv | | | | fair/poor | great/good | |
| 1 | 1 | 1 | 19d | Kitchen equip condition | Kitch & Serv | | | | fair/poor | great/good | |
| 1 | 1 | 1 | 19e | Kitchen lighting | Kitch & Serv | | | | dark | bright/OK | |
| 1 | 1 | 1 | 19f | Kitchen windows | Kitch & Serv | | | | no | yes | |
| 1 | 1 | 1 | 19g | Kitchen cleanliness | Kitch & Serv | | | | fair/poor | great/good | |
| 1 | 1 | 1 | 19h | Kitchen clutter | Kitch & Serv | | | | fair/poor | great/good | |
| *N/A* | *N/A* | | *20* | *Serving area location* | | | | | *N/A* | *N/A* | |
| 1 | 1 | | 21a | Menu item naming | | Display | | | by item | descriptive, creative | |
| 1 | 1 | | 21b | Menu location | Layout | | | | pre-order or before served | none, too high, or while serving | |
| 1 | 1 | | 22a | Serving-attractiveness | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 22b | Serving-physical condition | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 22c | Serving-equipment condition | Kitch & Serv | | | | fair/poor | great/good | |
| 1 | 1 | 1 | 22d | Serving-lighting | Kitch & Serv | | | | dark | bright/OK | |
| | 1 | | 22e | Serving-cleanliness | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 22f | Serving-clutter | Appearance | | | | fair/poor | great/good | |
| 1 | 1 | | 22g | Serving-food attractiveness | | Display | | | fair/poor | great/good | |
| 1 | 1 | | 23a | 1 of first 3 visible food items a F or V | | Display | | | no | yes | |
| 1 | 1 | | 23b | Serving tray use | | Serv method | | | no | yes | |
| 1 | 1 | 1 | 23c | Total # tray colors | | | Plate | | 1 color | >1 color | |
| 1 | 1 | 1 | 23d | Lunch tray material | | | Plate | | styrofoam, cardboard, bendable | plastic, not bendable | |

## **APPENDIX G**: CAFES codebook

| **INCLUSION** | | ***** | **CAFES item #** | **CAFES ITEM DESCRIPTION** | **SCALE/SUBSCALE** | | | | **CODING** | | **NOTES** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **CAFES study** | **Final CAFES** | | | | **ROOM** (subscale) | **TABLE** (subscale) | **PLATE** | **FOOD** | **0** | **1** | |
| 1 | 1 | | 23e | Serving tray rest | | Serv method | | | no | yes | |
| | *1* | | 23f | Multiple serving trips allowed | | Serv method | | | yes, for all | no; certain items | |
| | *1* | 1 | 23g | Multiple serving trips only for FV/healthy items | | Serv method | | | no | yes | |
| 1 | 1 | | 23h | Individual food/bev item labeling | | Display | | | none | some/all | |
| 1 | 1 | 1 | 23i | FV next to checkout | | Display | | | no | yes | |
| | 1 | | 23j | Ice cream available | | Availability | | | no | yes | |
| | 1 | 1 | 23k | Ice cream cooler transparency | | Display | | | transparent | opaque | |
| | 1 | 1 | 23l | Unhealthy options out of reach/by request only | | | | | no | yes | |
| 1 | 1 | 1 | 24 | Avg lunch tray area | | | Plate | | <100 $in^2$ | >100 $in^2$ | Based on CAFES study sample average |
| | 1 | | 25 | Utensil availability | | | Plate | | yes | no | Record "yes" if all utensils needed for meal are available |
| | 1 | | 26a | Fresh fruit availability | | Availability | | | yes | no | |
| 1 | 1 | 1 | 26b | Fruit presentation | | Display | | | metal/plastic tray | decorative bowl/display | |
| | 1 | 1 | 26c | Fresh fruit whole or sliced | | | | Food | whole | sliced, both | |
| 1 | 1 | 1 | 27a1 | FV trays or premeasured | | Serv method | | | premeasured | larger tray etc. | |
| 1 | 1 | 1 | 27a2 | FV packaging | | Serv method | | | not transparent | transparent | |
| 1 | 1 | 1 | 27b1 | Dessert trays or premeasured | | Serv method | | | larger tray etc. | premeasured | |
| 1 | 1 | 1 | 27b2 | Dessert packaging | | Serv method | | | transparent | not transparent | |
| 1 | 1 | 1 | 27c1 | Snack trays or premeasured | | Serv method | | | larger tray etc. | premeasured | |
| 1 | 1 | 1 | 27c2 | Snack packaging | | Serv method | | | transparent | not transparent | |
| 1 | 1 | | 28 | Milk display: <50% or $\geq$50% white | | Variety | | | <50% | $\geq$50% | |
| 1 | 1 | | 29a | LF unflavored milk location | | Display | | | behind flavored | in front of flavored; only LF white milk | |

## **APPENDIX G**: CAFES codebook

| INCLUSION | | * | CAFES item # | CAFES ITEM DESCRIPTION | SCALE/SUBSCALE | | | | CODING | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAFES study | Final CAFES | | | | ROOM (subscale) | TABLE (subscale) | PLATE | FOOD | 0 | 1 | |
| 1 | 1 | | 29b | White milk location | | Display | | | behind flavored | in front of flavored; only white milk | |
| 1 | 1 | | 30a | ≥1 fruit on tray | | | | Food | few/none | all/most | |
| 1 | 1 | | 30b | ≥1 veggie on tray | | | | Food | few/none | all/most | |
| 1 | 1 | | 30c | ≥1/2 FVs offered are raw | | | | Food | no | yes | |
| 1 | 1 | | 30d | Fried/breaded items offered | | | | Food | yes | no | |

**CAFES Codebook Column Header Descriptions:**

CAFES study = "1" indicates an item that was included in the present CAFES study analysis.
Final CAFES = "1" indicates an item included in the final CAFES version to be scored (vs. N/A).
* = indicates a CAFES item to be scored, but that is eliminated from the overall CAFES item count when the item does not apply to the school being observed.
CAFES item # = CAFES instrument item number.
CAFES item description = Abbreviated CAFES item description.
Scale/subscale = Indicates an item's scale and subscale (for room and table scales)
Coding = Abbreviated description of how to code (assign a 0 or 1) the item from the CAFES form.
Notes = Additional coding instructions.

**CAFES scoring instructions**

**a**. Each CAFES item receives a 0, 1, or * which indicates N/A.
**b**. *CAFES total*: count the total number of "1's."
**c**. *Completed CAFES items*: Subtract the total number of items answered with a * from 198 (total CAFES items possible).
**d**. *CAFES total score*: Divide (b.) by (c.) and multiply by 100. This is the total CAFES score out of 100%.
**e**. Repeat items b. – d. for room, table, plate and food scale items.
**f**. Repeat items b. – d. for items within each room and table scale subscale